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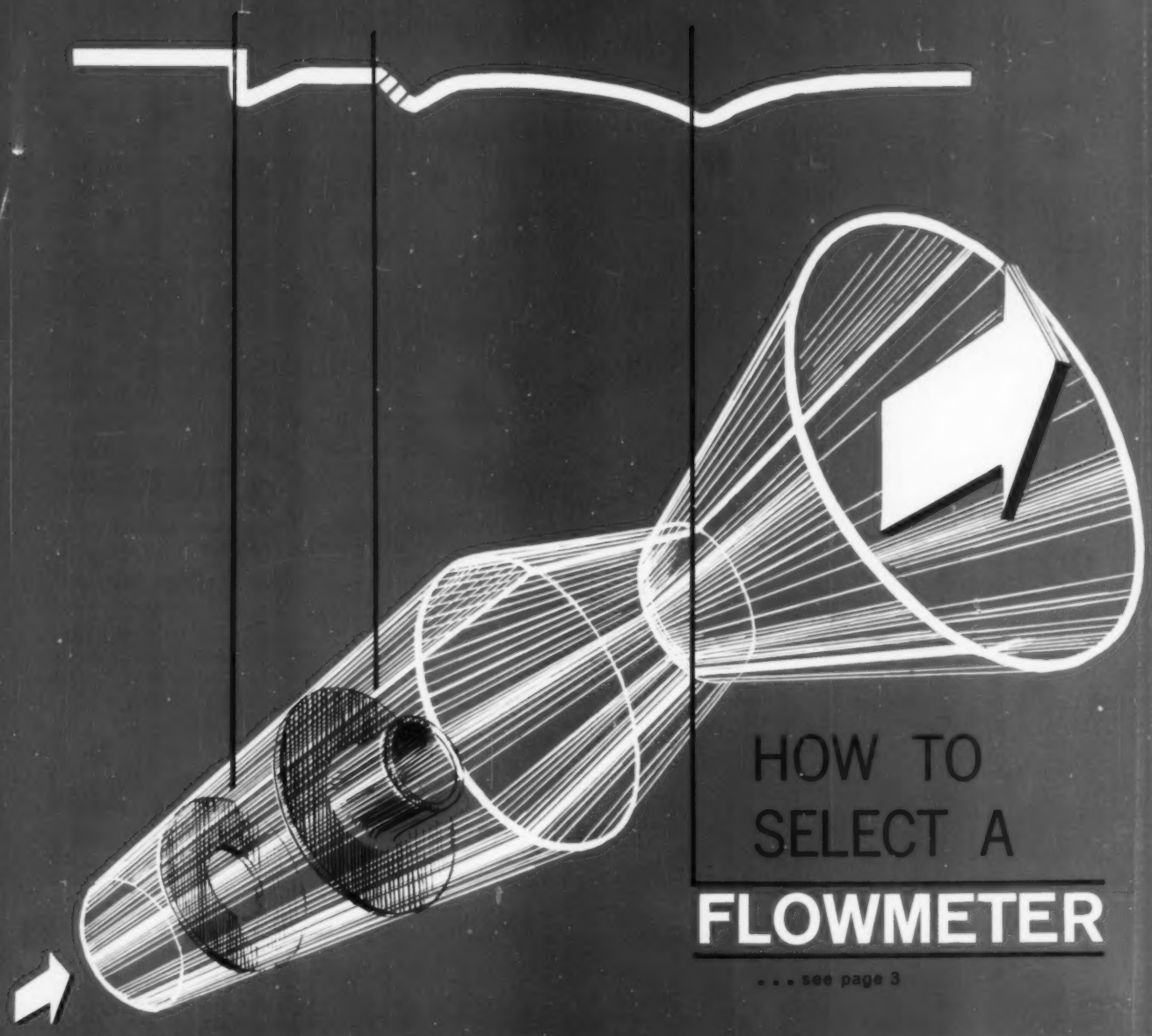
PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS MAY 8, 1961



HOW TO SELECT A FLOWMETER

. . . see page 3

SIMPLER ACCELERATION ANALYSIS OF MECHANISMS . . .

WHAT HEAT TREATMENT FOR PH STAINLESS STEEL . . .

LOADS FOR 18 CONSTANT STRENGTH BEAMS . . .

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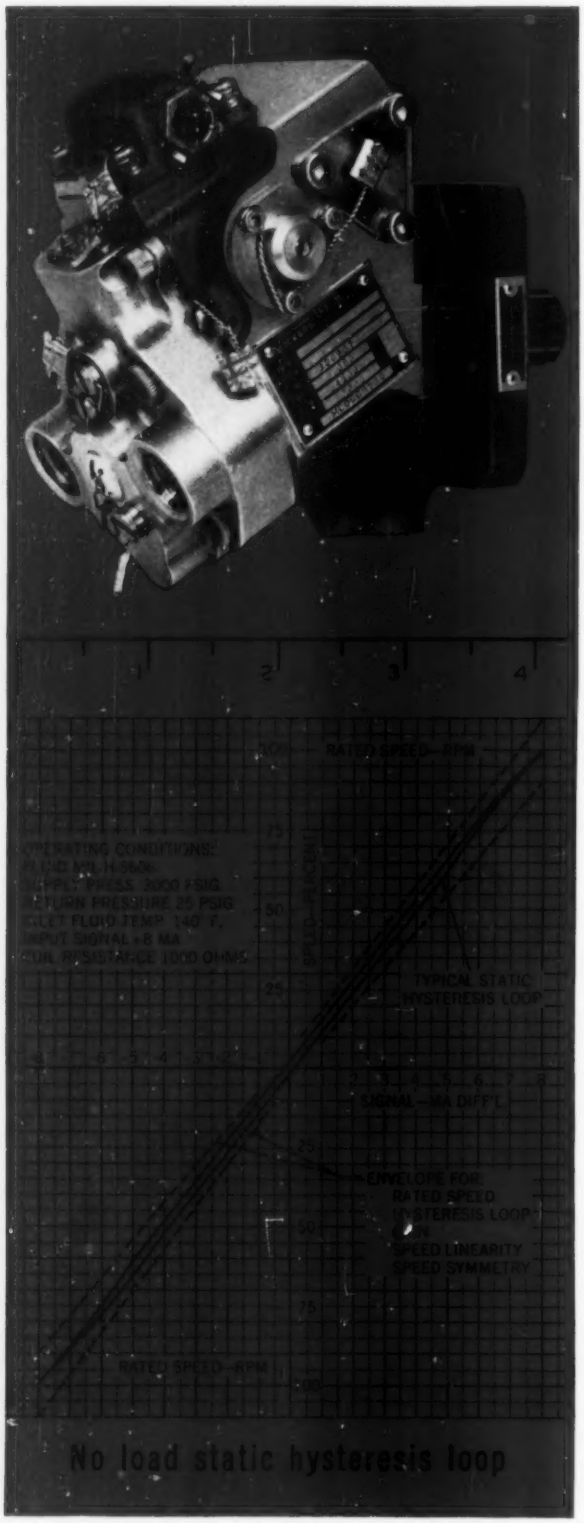

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PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS

May 8, 1961 Vol. 32, No. 19

FEATURED:

DEPARTMENTS:

INTERESTING TO NOTE 3
WHAT'S NEW IN RESEARCH 6
DEVELOPMENTS TO WATCH 8
THE ENGINEERING WEEK 15
POINTS OF VIEW 20
READER TO EDITOR 22
MEETINGS 23
FYI PERSONAL 24
HORIZONS 25
PRODUCT DESIGN 30
DESIGN FILE 47
SIGNIFICANT COMPONENTS 51
DESIGN LITERATURE 55
ADVERTISERS INDEX 60
READER SERVICE CARDS 61

ACCELERATION OF LOW-COMPLEXITY MECHANISMS . . . J Hirschhorn
Author tells what they are; gives his simpler analysis method 26

BEST HEAT TREATMENT FOR PH STAINLESS STEELS . . . D C Ludwigson
Fabrication method decides which hardening sequence is best 32

HOW TO SELECT A FLOWMETER . . . C C Miesse and O E Curth
Roundup of available types, and simplified selection procedure 35

SINGLE NOMOGRAPH FOR 18 CONSTANT-STRENGTH BEAMS . . . W Griffel
Finds total load the beam will carry, and maximum bending moment 47

FIELDS OF INTEREST REPRESENTED IN DEPARTMENTS:

MATERIALS:

Titanium alloys rated for weldability 6
Hot hardness is measured by rebound 6
Gold films tackle dry-lube jobs 8
New plastics family makes debut 10
Costs cut on aluminum superalloy 10

MECHANICAL:

Retainer reservoirs aid dry-film bearing lubrication 6
Tight fit improves pin joints 6
This tool control thinks ahead 8
Multiple adhesives multiply strength of joint 8
Face-type shaft seals disassembled, reassembled by hand 51

ELECTRICAL:

Anodizing process is key to higher temperature motors 10
Mechanical loading controls electrical switch 10
Control device blamed for Mercury-Atlas failure 18
Modular indicator light uses filter to give colors 51

PRODUCT DESIGNS:

Engines tailored for design needs 30

GENERAL:

Promise of new products spurs research growth 15
Summer instruction offered to engineers 17

I OF A SERIES

NOTES FROM A DESIGNER'S SKETCH BOOK

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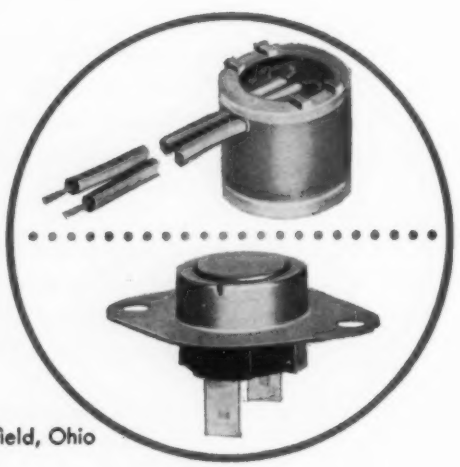

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INTERESTING TO NOTE

Flowmeters—This Month's Special Report

Scientists and engineers depend upon each other's labors in the development of many products, from concept to hardwear. Likewise, editors depend on collaboration with engineer and scientist in the preparation of feature articles. The Special Report, "How to Select a Flowmeter," is an example. Editors Frank Yeaple and Frank Hall asked Armour Research senior scientist Dr C. C. Miesse and his associate, O. E. Curth, to prepare a treatise on flowmeters. Their report was then passed along to two working engineers who evaluated the material and re-worked it with the design engineer in mind. You will find the result of six men's labors—about 300 man-hours of researching, writing, condensing and editing—reduced to the 12 pages starting on page 35.

Power—from Powder to Gasoline

If the invention of gunpowder did nothing else constructive, it at least made man consider it as a new power supply. Just as with the atomic bomb years later, gunpowder led scientists to seek peaceful uses for its destructive force. The first attempts to harness gunpowder in any sort of mechanism ended in failure. In the latter part of the 17th century, the Dutch scientist Christian Huygens, by burning some gunpowder in a cylinder, raised a balanced piston. But as soon as the gases cooled, atmospheric pressure forced the piston down.

After Huygens' death, Denis Papin tried his luck with the internal combustion engine, substituting the expansive force of steam for that of burning gunpowder. Again failure. The first internal combustion engine that actually ran was Cecil's hydrogen engine of 1820. This was a vacuum engine powered by exploding a mixture of hydrogen and air. Then, in 1859, a Frenchman, Etienne Lenoir, designed an engine that ran on a mixture of gas and air. Liquid fuel, burned outside a cylinder, produced combustion gases that entered it by a slide-valve mechanism similar to that of a steam engine.

Lenoir wasn't the only one making engines. In 1864, German salesman N. A. Otto teamed up with an engineer from Cologne, Eugen Langen, to produce an atmospheric engine that sold very well. Twelve years later, Otto invented his 4-cycle engine. It gave a tremendous impulse to the embryonic automobile industry in both Europe and America. (As a token of gratitude, Henry Ford commissioned a bust of Otto for his museum in Dearborn.) The 4-cycle engine didn't stop with automobiles. As the article on page 30 points out, a new die-cast aluminum engine promises many applications.

The Patent Story

In 1641, the Massachusetts General Court convened to discuss the question of granting Samuel Winslow a monopoly to make salt by his "novel method." The decision was yes—the first patent granted on this continent. Five years later, Joseph Jenkes appeared before the same court

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to request a patent for a certain type of mill to manufacture scythes. Again the court concurred, and Jankes became patent-holder No. 2. That's the way it went. For more than a century the only way to win a patent was by special appeal to the governing body in one of the Colonies.

Then came the Constitutional Convention, which met in Philadelphia in 1787. One subject discussed was a better method of granting protection to inventors and authors. Although there still existed a widespread fear of "monopolies" of the kind granted by European monarchs, no objection was raised to the principle of granting limited monopolies in the form of patents on inventions. On Aug 18, both James Madison of Virginia and Charles Pinckney of South Carolina submitted proposals regarding the protection of inventors by means of patents, and on Sep 5, a clause concerning patents was adopted by the convention.

Subsequently, on Apr 10, 1790, President George Washington signed the Patent Bill. For the first time in history the intrinsic right of an inventor to profit from his invention was recognized by law. The new law placed the responsibility for granting patents upon a board made up of the Secretary of State, Secretary of War and the Attorney General. This board could issue a patent for any period of time it deemed suitable—but not to exceed 14 years. This system of awarding patents had obvious drawbacks; also, the board became tied up in details and couldn't function smoothly. Three years after its inception it was abolished, and the Secretary of State was given sole responsibility for granting patents. To receive a patent, an applicant merely submitted drawings, paid a $30 application fee, and the rest was just a clerical function.

In 1836, Sen John Ruggles of Maine completed a report which stated that "for more than 40 years the Department of State has issued patents on every application, without any examination into the merits or novelty of the invention. Many patents granted are worthless and void and conflict upon one another, and a great many law suits arise from this condition." This led Congress to pass a new law, establishing the so-called "American" system of granting patents. And nine days after Congress acted, Patent No. 1 was issued for a "locomotive steam-engine for rail and other roads." Its recipient—the same senator from Maine, John Ruggles.

David L. Laddis, our newly designated Commissioner of Patents.

This year therefore marks the 125th anniversary of the US Patent Office. To date, it has granted more than three million patents. The basic patent system has remained relatively intact since 1836, although there have been many suggestions for improvements. On page 20 an engineer takes a look at our patent system and presents a point of view that bears consideration.

Benedict A Leerburger Jr

NEXT WEEK IN PRODUCT ENGINEERING

. . . **Value—The Rising Emphasis in Design**

Chief editor E. J. Tangerman prepared this special study of specialist services in design engineering—reliability, value analysis, value engineering, quality assurance.

. . . **New Developments in Bearing and Gear Lubrication**

Handy equations, design charts and performance data enriched this year's ASLE meeting. Here's an on-the-spot report.

. . . **Closer Look at Fiberglass-reinforced Thermoplastics**

As with thermosets, the technique creates entirely new materials, which bring the performance of thermo-plastics nearer to that of metals.

. . . **How to Put Flexible Tubing to Work**

Its ability to conduct air, liquid, dust and granular solids through cramped passages and around obstructions, in a variety of environments, solves many design problems.

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CIRCLE 5 ON READER SERVICE CARD 5

WHAT'S HAPPENING IN RESEARCH . . .

Titanium alloys rated for weldability

Top rating for weld ductility goes to Ti-2.5 Al-16 V, says CalTech's Jet Propulsion Lab. It's been making bend tests on half a dozen high-strength alloys (yield strengths in excess of 150,000 psi) and rates the materials in this order: 2.5 Al-16 V (most weldable), B 120 VCA, 6 Al-4 V, 3 Al-6 Mo, 4 Al-3 Mo-1V, and RS 140 (least weldable).

Samples welded after aging showed larger fracture deflections and smaller moduli of rupture than those welded before aging.

Retainer reservoirs aid dry-film bearing lubrication

Modification of bearing retainers to provide small, reservoir-like depressions in retainer-ball pockets can significantly improve the performance of dry-film lubricants at elevated temperatures, the Naval Air Materials Center reports.

Tool-steel bearings operating in such modified cast iron retainers showed a useful performance at 750 F and 3500 rpm of several hundred hours. For the tests, Navy used its own dry-film composition, a molybdenum disulfide-graphite-sodium silicate mixture.

Work is now in progress to determine the optimum reservoir geometry. A report on results thus far is to be presented by M. J. Devine, E. R. Lamson, and J. H. Bowen Jr of NAMC at this week's ASME lubrication symposium.

Tight fit improves pin joints

Fatigue strength of pin joints can be increased by using a tighter fit than is normally specified, says Britain's National Engineering Laboratory.

In fork-and-tongue connections joined by a transverse pin, NEL recommends using a larger pin than would be suggested by elastic stress analysis, with a high interference fit between pin and tongue. Fluctuating-load tests indicate that capacity of such joints can be increased by a factor of 8 or more (from about 2000 lb to nearly 20,000) for a life of 10 million cycles.

To get around assembly problems posed by interferences on the order of 0.008 in./in. of dia., interference-fit bushings can be used. They can be pressed in prior to joint assembly with clearance fit pin; and, NEL says, the completed joint shows a strength comparable to those having solid pins.

Atom briefs . . .

Boron can protect tantalum from oxidation at temperatures to 3200 F in air, as well as from attack by molten metals, AEC researchers report. By depositing an elemental boron coating on tantalum parts and then converting that coating to a tantalum monoboride composition, an adherent deposit is formed. Primary aim of the development was to permit tantalum's use in liquid-metal-fueled nuclear reactors. Information on the process, as applied for that purpose, is contained in a British patent (840,203).

A new research program on high-temperature materials may replace the now-cancelled nuclear aircraft project. AEC has requested $25 million for basic studies of materials and components, and believes the results will have broad applications outside the nuclear aircraft field. **—ARG**

Rebound measures hot hardness

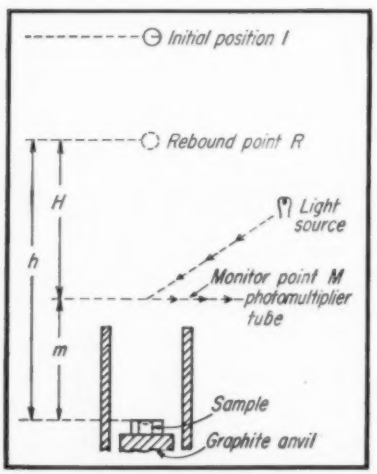
The bouncing of a tungsten carbide ball, remotely and electronically monitored, is providing Britain's Cavendish Laboratory with an effective way to measure hardness of refractory materials. Measurements have been made at temperatures as high as 3000 F on such materials as titanium carbide, and tungsten carbide itself.

Interestingly, while all the refractories tested decrease in hardness as the temperature increases, the patterns of change differ. The hardness of tungsten carbide, as measured by height of rebound, decreases almost linearly over the full range; while titanium carbide holds almost constant to about 1800 F and then drops off sharply.

The equipment consists of a resistance-heated vacuum furnace, fitted with a ball-dropping and magnetic ball-catching mechanism; and a light source, photo-multiplier tube and electronic counter for monitoring height of rebound. Specimens are disk-shaped, ½ to 1 in. dia and thickness. Balls are ⅛ in. dia, and are dropped from a height of 22 in.

The diagram shows how the monitoring system works. As the ball drops from its initial position *I* past the monitoring point *M*, the system comes into action; but counting does not start until it rebounds past *M* on its way to the rebound point. As it falls back past *M*, counting stops. The total time count, from *M* to *R* and back to *M*, makes it possible to calculate height $H = \frac{1}{2} gt^2$, where t is ½ the total time count. Adding the fixed distance m gives the total height of rebound (h), which may be plotted directly against temperature.

There are still problems in design, but results are reproducible.



HOT HARDNESS of specimen supported on graphite block is measured by time-of-flight determinations. Since ball itself is held outside furnace, and spends little time inside, it is not likely to soften or overheat.

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DEVELOPMENTS TO WATCH...

Multiple adhesives multiply strength of joints

By combining adhesives—using several types in a single joint—it's possible to increase structural strength as much as 25%, says S. J. Dastin of Republic Aviation. The technique does not just involve chemical mixing of the compounds; but, also, specification of different adhesive formulations for different parts of the joint.

Tests were made on high-strength steel rocket motor cases using overlapping ring construction; and the "composite" adhesives were so selected and applied that shear modulus would be at a maximum at the center, tapering off towards the ends. Joints made this way, says Dastin, show a strength of 3900 psi, as compared to 3100 psi for those made with the best available conventional adhesives.

In a typical joint, the center section may be an epoxy-phenolic combination; the intermediate sections, vinyl-phenolic; and the closure sections, acrylonitrile-phenolic.

Republic has patented one "composite adhesive" system and is now investigating other combinations, using polyamide-epoxies, rubber-phenolic-epoxies, and epoxy-silicone-phenolics in addition to those mentioned above.

Gold films tackle dry-lube jobs

To the growing list of unusual materials being tested as high-temperature dry lubricants (*PE*—May 1, p 6), Southwest Research Institute now adds gold. With thin, vapor-deposited gold films, coefficients of friction less than 0.2 have been obtained under a variety of test conditions ranging from room temperature to 2000 F and from atmospheric pressure to 10^{-8} mm Hg.

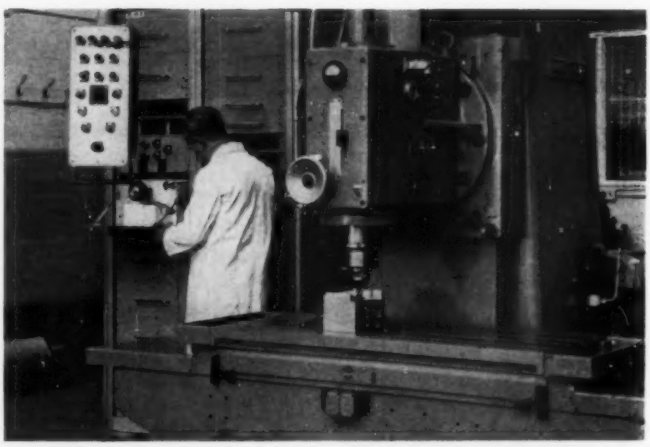
Several tests were run of precious-metal film lubrication on cermets in air at high temperature (1600 F), for times ranging from one to five hours, at contact pressures of 7500 psi, and rubbing speeds of 20 fpm; the resulting wear tracks had a high polish.

SRI is also working on new cermet materials for the bearings themselves (*PE*—Apr 24, p 9), and is investigating gas-formed surface compounds and a variety of glasses and dry powders as lubricants-of-the-future.

This tool control thinks ahead

A tool control that stops the machine before it makes a machining error has been developed by EMI Electronics Ltd and is now undergoing extensive shop tests.

It's an angle safety unit which derives its control information from the built-in computer that controls the machine. However, EMI says, since it continually has access to the computer output before it is actually used to control the machine, it is able to predict a fault and stop the machine before the machine follows the mistake.



VERTICAL MILLING MACHINE was chosen for test installation of fault-detection system because of its sturdy design and adaptability to automatic contour-control system (installed here at left).

In EMI's contour-control system, a resolver, the angle of whose shaft continually indicates the angle of the surface of the contour at the point being cut, shows how much the machine has just been told to move and how much it is going to be told to move.

If angle of the surface changes suddenly by more than a preset amount due to an offset point, the advance information sampling immediately detects the transient and trips the safety circuits.

Nickel-Chrome Plating shines through the years of wear she'll give this bicycle

Nickel-Chrome Plating is more than a match for the hard wear that means bicycling fun for youngsters. It's beautiful, it's durable—*and stays that way*—despite rain, dust, bumps and scratches.

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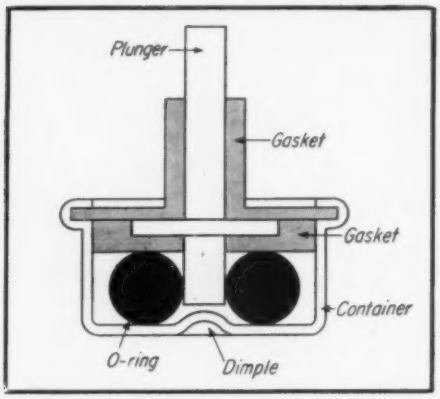
Mechanical loading controls electrical switch

A miniature electrical switch that closes when a predetermined weight load is applied has been patented by two Union Carbide engineers.

It has a cupped metal container, dimpled at the bottom, in which a flanged metal plunger moves (see diagram). At bottom of the cup, supporting the plunger, is a resilient, nonconductive O-ring. Spacing and materials are so chosen that when a predetermined load is applied, the ring is compressed, and the plunger makes contact with the dimple, closing the switch. Its designers say the switch may be used in circuits which require abnormally high resistances when the contacts are open (resistance values can be on the order of 1×10^{13} ohms if fluorocarbon gaskets are used at top and bottom); and the entire switch can be encapsulated for submerged use. A broad range of operating temperatures is possible too, through proper selection of materials for O-rings and gaskets. (Silicone rubber, for instance, will permit operation from −40 to 160 F.)



WEIGHT-ACTIVATED SWITCH closes when plunger makes contact with dimple. The flange on the gasket serves as a seal.

Anodizing process is key to higher-temp motors

A new process for anodizing aluminum magnet wire is permitting North American Aviation to design motors for long-term operation at 600 F and above. The process is a reversal of standard techniques. Instead of using pre-anodized wire for winding the coils, NAA does the winding first, then anodizes (using a specially controlled chromic acid process), and finishes the job with an oil sealant in place of the commonly used dichromate solutions. This way, E. Clements of NAA says, higher quality (less brittle) coatings with a dielectric strength of 1400 volts/mil are obtained, and at substantially lower cost.

The encapsulating system for these coils is novel too. After testing a wide variety of compounds, NAA settled on a fibrous ceramic cement—a material ordinarily employed to hold strain gages in place for high-temperature testing.

The system is now in use on thrust actuator motors, and others are in the design stage.

New plastics family makes debut

Soft, pliable olefin plastics of a new type, similar to vinyls in many respects but offering several advantages over them, are on the way.

The materials: ethylene-ethyl acrylate copolymers. They can be injection-molded on conventional equipment, need no compounding and no plasticizers to achieve their flexibility, and are potentially low in cost, particularly since they are compatible with low-cost fillers.

First on the market is Dow, with a material priced at 32½¢/lb in truckload quantities. But another company holds basic patents in the field and a third is actively pursuing polymerization research.

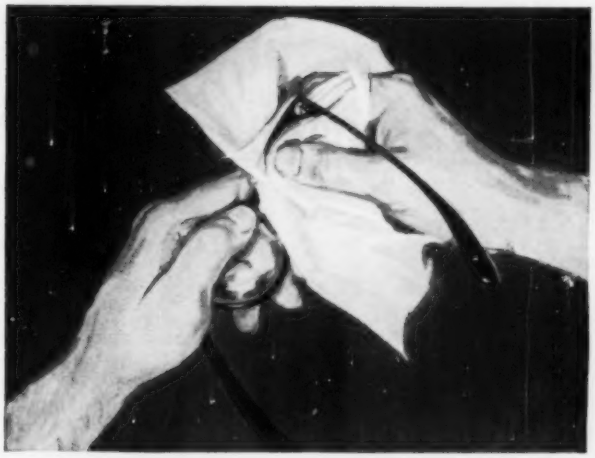
Costs cut on aluminum superalloy

High-strength cast aluminum at 25% lower cost is promised by Reynolds Metals Co as it gets ready to market a civilian version of Tens-50. This superalloy has thus far found its major application in military products.

The new version, says Reynolds, is similar to Tens-50; but beryllium content has been sharply reduced. This means a substantial reduction in alloy cost. However, since the function of the beryllium is to overcome brittleness caused by impurities, the lower percentage will mean need for closer control in the foundry to achieve the low porosity, desirable chill, and strength (close to 50,000 psi) that characterize the original alloy.

—ARG

An example of Avisco Rayons in Industry



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Avisco rayon fibers are ideal for making non-wovens on your existing wet system because fiber lengths, diameters and physical properties can be precisely controlled. You get all the economy of high-speed wet system operation plus the tremendous versatility of rayon.

Non-wovens of Avisco rayon can be made lustrous or dull, strong, flexible, drapable. Consider these fibers for napkins, table cloths, wiping cloths, filters, hospital sheets and pillow cases, disposable garments of all types, draperies and other applications both industrial and domestic.

Write for information on rayon in non-wovens, produced on the wet system. Send in the Quick Reply Coupon at right.

QUICK REPLY COUPON 8-6

Industrial Merchandising Division
American Viscose Corporation
350 Fifth Avenue, New York 1, N.Y.

Please contact me about Avisco Rayons for use in the following application:_____

Name_____

Company_____

Address_____

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CIRCLE 11 ON READER SERVICE CARD 11

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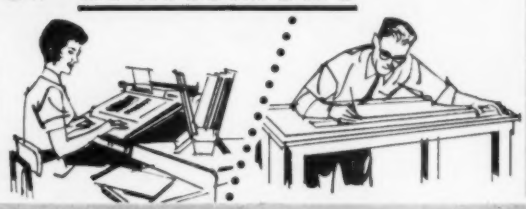

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Hamilton CL 100 Drafting Table
Conserves dollars, yet rugged canted-leg design provides modern styling and convenience with long-term durability.

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This new 36 page booklet describes a wide variety of engineering and production problems that have been solved with advance techniques in drafting and printmaking pioneered by Dietzgen. The concise, problem-solution approach suggests ways in which you may improve the efficiency within your engineering department or eliminate production bottlenecks. Write today on your company letterhead for the Mechanics of Modern Miracles. Ask for Publication SPD2-A10. Eugene Dietzgen Co., Chicago 14, Illinois

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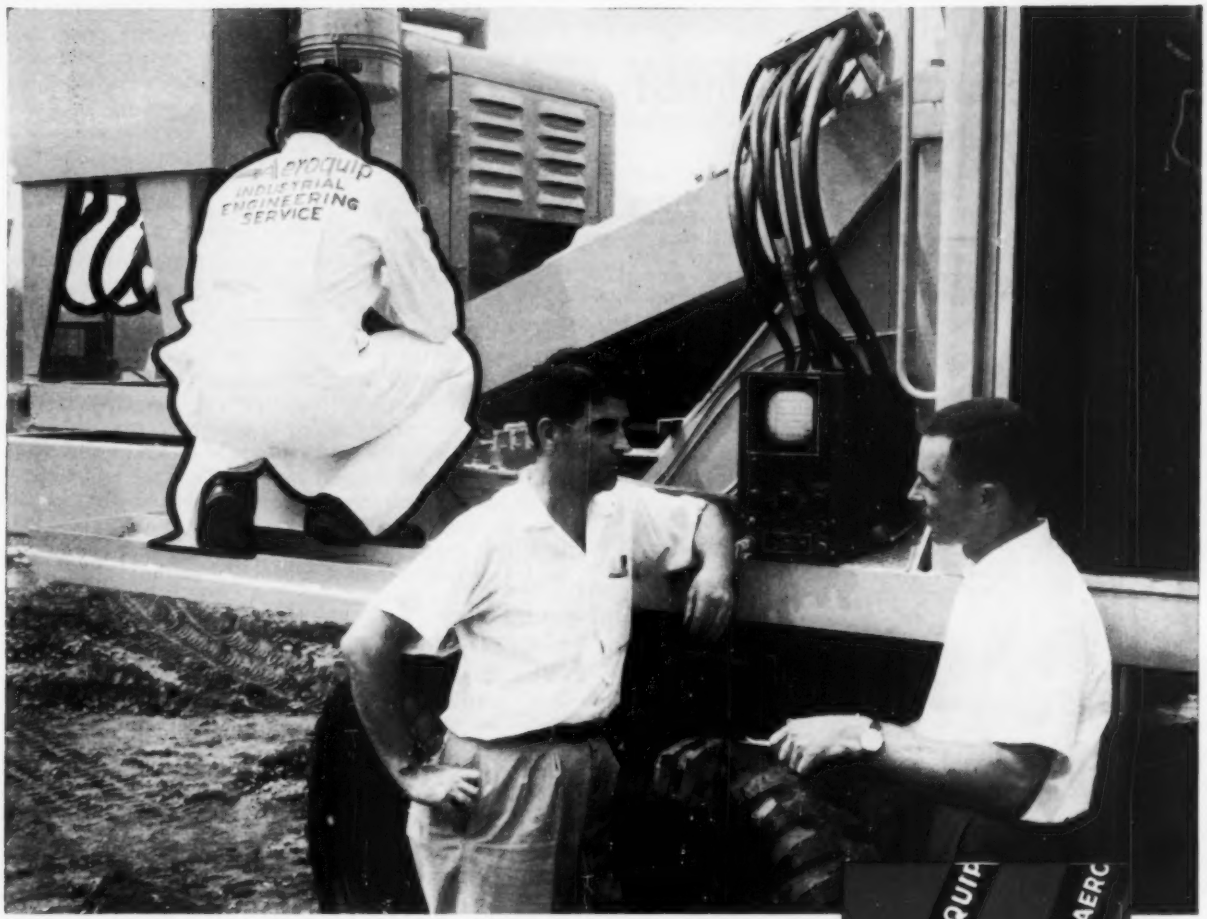

How Aeroquip Prototype Plumbing Service Reduces Your Design Costs

Aeroquip's Fluid Piping Service offers major equipment manufacturers many time-saving and money-saving advantages at the prototype stage. Applying unmatched fluid piping experience, highly skilled Aeroquip specialists can assist your engineers in checking flow and pressure characteristics, installation, routing, and support clamping on fluid piping. Expert recommendations can help eliminate potential problems which might arise later, requiring costly modification.

Backed by the most complete line of fluid piping products, Aeroquip's experienced engineering team can also provide assistance in design, production, service parts and after-sales service in the field. This unique start-to-finish fluid piping service helps assure maximum performance, long life, greater owner satisfaction and reduced field service complaints.

For complete details, call your nearby Aeroquip sales engineer, or write to us.

- DESIGN
- PROTOTYPE
- PRODUCTION
- FIELD SERVICE
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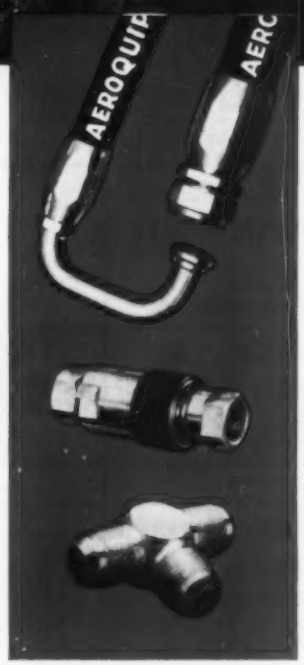
Aeroquip fluid piping specialists can work with you in every phase of manufacture to assure maximum performance of fluid piping systems on your products.



Aeroquip now produces a wide range of fluid piping products, including hose assemblies with standard or special tube configuration fittings, Self-Sealing Couplings and a new line of tube fittings.

Aeroquip

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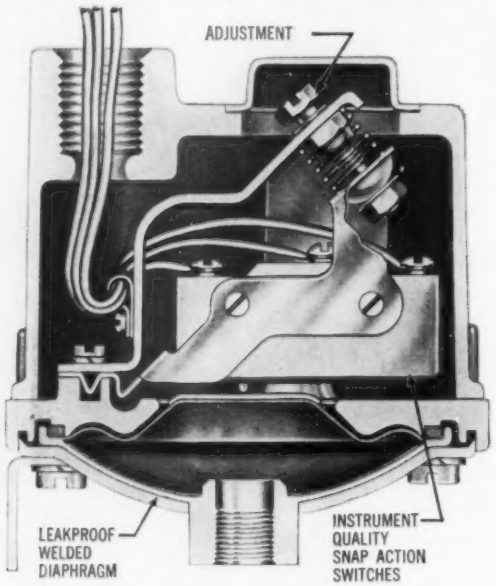
BREAKTHROUGH IN PRESSURE SWITCH ACCURACY

at reduced prices

The high accuracy associated with instruments costing several hundred dollars is now obtainable with new Barksdale pressure switches at a retail cost of $19.00 to $30.00. Accuracy of ±0.5% is guaranteed and ±0.2% accuracy can be supplied when required. Substantial price reduction is accomplished by use of erector set design and a major investment in production tooling. A wide choice of "tailored to the job" features (see column at right) meets your specification requirements exactly.



THESE POINTS ARE IMPORTANT

WE BUILD IN	WE DON'T USE
EXTREME ACCURACY and DEPENDABILITY maintained during operating life due to direct acting design	LINKAGES & BEARINGS which, as they wear, make the setting of the pressure switch drift.
OPERATION IN ANY POSITION which saves the installation costs encountered in mounting a switch that uses liquid switching elements	LIQUID SWITCHING ELEMENTS which make the switch difficult to mount and very critical to vibration.
IMMUNITY TO VIBRATION you can mount the switch directly on your vibrating or moving equipment.	ACCORDION BELLOWS which make the pressure switch sensitive to vibration.

PRESSURE SWITCH DIVISION

Barksdale valves

5125 Alcoa Avenue, Los Angeles 58, California

New line of Barksdale pressure switches announced

Improved accuracy, reduced cost and higher proof pressures are advantages made possible by design innovations in the new Barksdale diaphragm pressure switches. Accuracy of ±0.5% as compared to the customary ±1.0% is guaranteed, and each unit is tested for repeat accuracy of set point and re-set point before shipment. Accuracies of ±0.2% are available on request.

Erector set design offers dual benefit

The basic unit of all Barksdale diaphragm pressure switches is a diaphragm surrounded by a heavy protective capsule to which components may be attached as required. Addition of a switch, switch bracket and adjusting bracket to the basic unit makes a stripped switch for use in a common cabinet with other electrical devices. (Original equipment manufacturers need not pay for a housing which is not needed.) Addition of a sealed housing to the stripped switch completes a weather- and vapor-tight switch unit. A standard housing with integral terminal block or an explosion proof housing with integral terminal block may be specified. Erector set construction allows a wide choice in specifications that approximates a custom made switch and permits use of cost-cutting mass production methods that are reflected in lower prices.

Proof pressures to 600 psi

In the low settings the new Barksdale pressure switches will actuate at 0.1" mercury with proof pressure to 10 psi. In higher ranges they will go up to 600 psi proof pressure at settings to 400 psi. This makes it possible to use inexpensive diaphragm pressure switches on installations that presently require higher priced bourdon tube switches.

Important additional advantages

Because the housings of Barksdale pressure switches are independent of the sensing and switching mechanisms changes in ambient temperature will not throw these switches out of adjustment.

The adjustment brackets are specially designed to protect switch terminals against shorting during adjustment.

Lead wires are held down by a tension clip. They cannot be pulled out accidently and thereby throw off the switch adjustment.

Mounting brackets may be oriented in any of four directions.

Tamper proof adjustment covers have servicing instructions on the inside to allow for painting of the units.

Standard pressure connection is ¼" n.p.t. female pipe fitting. One-half inch fittings suitable for mounting directly on ½" pipe can be supplied on request.

Standard housing has ½" nps conduit connections and a terminal block. The latter is accessible without removing the housing by lifting a cover plate.

Ask for new catalog and handbook

Complete details on Barksdale diaphragm, piston and bourdon tube pressure switches are included in a new catalog and handbook. This free book is a practical aid in planning the vital link between your electric and hydraulic circuits. It contains a glossary of terms, a schematic demonstration of operating characteristics, and a suggested step-by-step procedure for simplifying pressure switch selection. In addition, the book gives a complete run-down on all the detail features leading to the unit that answers your specific control problems. Send for your copy now, or ask your Barksdale representative.

THE ENGINEERING WEEK

Promise of New Products Spurs Research Growth

NEW YORK—If the recession of the past 9 month has cast a gloom on corporate financial offices, it has not shown on their R & D budgets. A survey just released by the McGraw-Hill Department of Economics indicates that research this year will touch $10.5 billion compared with $9.8 billion last year. And company managements envision an increase to $11.7 billion by 1964. The figures include only that portion of government R & D being spent by industry; it excludes government R & D at universities and government labs.

The increases are universal throughout all industry. One of the largest gains this year shows up in electrical equipment, where R & D is expected to rise 11% over 1960, reaching $2.017 billion. The aircraft industry remains the largest R & D spender, with composite budgets amounting to $3.721 billion—a 7% gain over last year. This level is expected to hold through 1964. Looking ahead, machinery may be about to show one of the sharpest growth curves in industry. Already, it plans to spend $827 million on R & D in 1964—a 15% rise over this year.

NEW PRODUCTS, THE GOAL

Product development is a powerful impetus behind these programs. Overall, manufacturing firms anticipate that 14% of their 1964 sales will be in products not now existing, or substantially altered. This is the highest rate of new-product expectations yet uncovered by one of the McGraw-Hill surveys. Transportation equipment dominates the statistics with some 29% of projected 1964 sales in items not now on the market. Also significantly above average are the machinery industry with 23%, chemicals with 20%, and electrical machinery with 16%.

How reliable are such judgments? Can a company predict three years in advance whether its R & D projects will proceed on schedule, and, if so, will anticipated markets still exist? To this, the McGraw-Hill economists reply that industry has been remarkably accurate in the past. One survey question asked how much of 1960 sales were in products not existing in 1956. Over-all, industry answered 10%—exactly what was predicted four years ago. Each industrial group (i.e., aircraft, electrical machinery, etc.) came within 5% of earlier expectations.

A considerable portion of this year's R & D won't begin showing until well after 1964. To a question on how long it takes research to pay off, most companies—about 55%—answered three years or less. But for the remainder the period may be much longer. About 34% answered 4 to 5 years; 11%, six years or longer. A sizable portion of the payoff, too, will probably show in commercial as opposed to military products. For manufacturing as a whole, 57% of R & D is commercially oriented. This includes all research in food, paper and fabricated metals. In aircraft, on the other hand, 91% is for the military.

With so much research on tap, industry is finding it necessary to build many new labs. This year, $653 million will go into new research facilities—nearly 5% of industry's total capital investment. The chemicals industry leads with $123 million, followed by transportation equipment with $92 million.

PLANT MODERNIZATION IS SPUR

Considerable stimulus to new-product development, as well as sales, doubtless derives from the intensifying efforts of manufacturing industries to modernize facilities. These effects may be especially felt by machinery and other original-equipment suppliers. The trend toward replacing obsolete equipment first began showing in earnest in 1958. This year, the manufacturing industry has allocated $14 billion to new plant and equipment. Of

WHAT PORTION OF SALES ARE NEW PRODUCTS?

Industry	Actual % of 1960 Sales	Expected % of 1964 Sales
Iron & steel	5%	7%
Nonferrous metals	8	11
Machinery	14	23
Electrical machinery	12	16
Autos, trucks & parts	10	11
Transportation equipment	35	29
Fabricated metals & instruments	17	13
Chemicals	16	20
Paper & pulp	9	12
Rubber	2	7
Stone, clay & glass	9	13
Petroleum & coal products	2	5
Food & beverages	6	12
Textiles	9	10
Miscellaneous manufacturing	6	11
ALL MANUFACTURING	**10**	**14**

R & D TREND IS STILL UPWARD

(millions of dollars)

Industry	Spent in 1960	Planned for 1961	1964
Primary metals	$143.6	$153.7	$175.2
Machinery	684.8	719.0	826.9
Electrical equipment	1816.9	2016.8	2440.3
Aircraft & parts	3477.8	3721.2	3721.2
Fabricated metals & ordnance	258.7	266.5	333.1
Professional & sci. instruments	436.5	467.1	588.5
Chemicals & allied products	741.2	785.7	919.3
Paper & allied products	69.1	75.3	93.4
Rubber products	89.3	93.8	108.8
Stone, clay & glass	86.1	90.4	111.2
Petroleum products	309.7	319.0	338.1
Food & kindred products	106.9	117.6	144.6
Textiles & apparel	37.0	38.8	46.6
Other manufacturing*	1097.8	1130.7	1266.4
ALL MANUFACTURING	**9355.4**	**9995.6**	**11113.6**
Nonmanufacturing	415.1	481.5	577.8
ALL INDUSTRIES	**9770.5**	**10477.1**	**11691.4**

* Includes tobacco, lumber and wood products, furniture, printing and publishing, transportation equipment other than aircraft, and miscellaneous manufacturing industries.

this, 70% is earmarked for modernization, rather than expansion of facilities.

This trend is especially dominant in the auto industry. There, 91% of the $1.14 billion set aside for capital investment will go for replacing outdated equipment. Likewise, petroleum and coal industries will divert 89% of their $2.85-billion capital budgets into modernization; iron and steel, 85% of their $1.18-budgets, and machinery, 74% of its $1.14-investments.

Moonlight Converted into Guide for Satellite

YORKTOWN, NY—A light-detecting device, sensitive enough to sense weak rays from the moon, has been developed by IBM for NASA's Goddard Space Flight Center. It is expected to have applications as a detector in satellite optical systems.

The tiny device, which is based on the principle of a semiconductor-electrolyte, uses silicon for semiconductor and sulfuric acid for the electrolyte. It is said to be up to 10 times more sensitive than conventional devices, largely because the electrolyte is transparent, permitting more light to reach the junction of the semiconductor material, where electrical voltage is induced. In the usual photo diode or solar cell, made up of two layers of semiconductor material, much of the light impinging on the device is absorbed by the semiconductor materials before reaching the junction where the rays are converted into electrical energy.

In space applications, the new device will be used to flash electric signals to earth, giving missile trackers data for computing satellite spin axis, and therefore the direction that the instrument package is pointing. Data are obtained as the rotating satellite intermittently catches light from the moon or sun. The light, impinging on the detector, is converted into electrical impulses for transmission.

IBM's photoconductor is said to require very little power—1.36 volts—will reportedly supply it for several years. It is also rugged enough to withstand mechanical forces occurring during firing of a satellite. ■

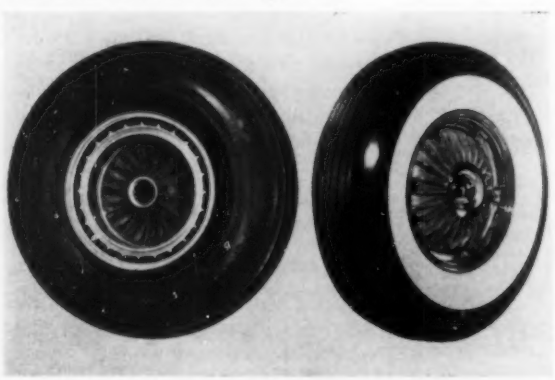
Schools Announce This Summer's Short Courses for Engineers

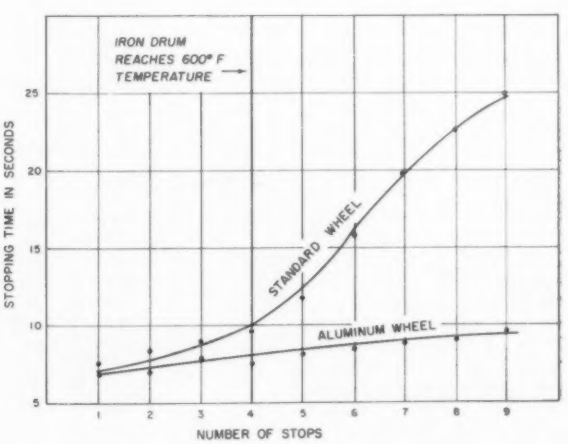
NEW YORK—Again this year, many universities are offering short courses for practicing engineers whose jobs require mastery of technologies that are advancing rapidly. The chart on next page selects a few that may be of special interest to product designers.

Many of the schools offer other courses. A complete listing can be easily obtained by writing to the addresses shown on the chart. Among schools with large-scale summer programs are MIT, the Univ of Michigan, Penn State Univ and Case. MIT will offer 26 different courses this summer in such specialties as metallurgy, electrical engineering, and operations research. Michigan's program includes 27 courses—among them infrared technology, flight mechanics of space vehicles, nuclear power reactor engineering, and various phases of computer engineering and programming. At Penn State, the 13-course program includes an updated version of last year's acoustics and missile engineering and a new program on "Survival in the Nuclear Age." All courses at Case are oriented toward computer technology.

Fees listed in the chart generally include all materials required for the course—plus a cocktail party or banquet in a few cases. But excepting the management course at the Univ of Georgia, the student will have to pay for his own room and most of his board. In many cases, accommodations can be arranged at the university for roughly $15 a week and up. Food depends upon the student's appetite and taste. ■

Aluminum Wheel Outbrakes Its Steel Disk Counterpart





Steel disk wheels may soon go the way of wooden spoke wheels. This prediction by Kaiser Aluminum and Bendix Corp is based on a series of tests, conducted on various aluminum wheel designs (photo left) in cooperation with various auto companies. According to Kaiser, these tests have demonstrated that brake linings rapidly lose effectiveness after drum temperature reaches 600 F; and aluminum drums are better able to remain within this critical temperature than steel. In operational tests, wheels of the two materials were braked 16 consecutive times at 70 mph. The drum temperature of aluminum leveled off at 500 F, steel rose to 925 F. With rising temperature, stopping time for standard production wheels increased from 7 to 25 sec; that of the cooler integrated aluminum wheel ranged from 7⅛ to 9⅛ sec (see chart). Kaiser adds that the light-metal wheels have been fatigue-tested to 500,000 cycles without failure—well above the 8000 to 85,000 cycles accepted for conventional wheels. With volume production, the wheels should add no more than $12 to the price of a car, Kaiser predicts.

SOME SUMMER INSTRUCTION OFFERED TO ENGINEERS

SCHOOL AND COURSE	DATE	TUITION	FOR INFORMATION
MASSACHUSETTS INSTITUTE OF TECHNOLOGY			Director of Summer Session, Room 7–101 Massachusetts Institute of Technology Cambridge 39, Mass.
Industrial Photoelasticity—discusses fundamentals of 2-dimensional & recent techniques for 3-dimensional problems on a beginner's level.	June 19–23	$200	
Fundamentals of Strain Gage Techniques—lectures cover wire, foil and semiconductor types of strain gages on a beginner's level.	July 10–14	$175	
Applications of Strain Gage Techniques—supplements the fundamental course (above), designed to give students skill in handling equipment.	July 17–21	$175	
Nondestructive Testing—lectures discuss magnetic-particle, fluid-penetrant, X-ray, ultrasonic and eddy-current methods of nondestructive testing. Open both to degree-holding beginners and experienced engineers.	June 26–30	$200	
Experimental Techniques—course discusses techniques for assembling experimental equipment and taking measurements by optical, pneumatic, hydraulic, radioisotope and electrical equipment methods. For professionals who design experiments.	June 13–23	$300	
UNIVERSITY OF MICHIGAN			Engineering Summer Conferences, 126B West Engineering Building, Univ. of Michigan, Ann Arbor
Machinability of Metals—lectures cover new materials and techniques for practicing engineers concerned with design or machining parts and products.	June 19–24	$185	
Applications of Stress Analysis to Design and Metallurgy—surveys principles and methods of applying stress analysis to engineering design, materials specification, etc. Planned for engineers, designers and metallurgists.	July 24–28	$160	
Semiconductor Theory and Technology—first week reviews chemical and physical principles underlying semiconductors, second week concentrates on semiconductor materials, fabrication techniques, surfaces and diffusion problems.	June 19–30	$275	
Human Engineering Concepts & Theory—covers current trends in human-factors research and application as they apply to engineers designing man-machine systems.	June 17–30	$275	
PENNSYLVANIA STATE UNIVERSITY			Engineering Seminars Conference Center Pennsylvania State Univ. University Park, Penna
Solid State Mechanics—course evaluates new methods for understanding stress-strain properties of materials and applications of these methods to design. Open to research, design and materials engineers.	June 11–23	$175	
Electrical Contacts—emphasizes theory and practice of electrical contacts including static, sliding and commutation, with emphasis on applications.	June 11–16	$90	
R & D Management Development—a skill builder in administration and human relations for engineers, physicists, and mathematicians now serving as project engineers, supervisors or leaders in R & D.	June 25–30	$95	
CASE INSTITUTE OF TECHNOLOGY			Herbert S. Schultz Jr, manager of special programs, Case Institute of Technology University Circle, Cleveland 6
Generalized Electrical Machine Theory—course introduces new method for analysis of rotating electrical machinery and emphasizes a general technique for determining dynamic-transfer functions of DC polyphase induction and synchronous machines.	July 17–21	$200	
Digital Control Systems Engineering—subject matter includes Boolean algebra, number systems, logical elements, analog-digital conversion, etc., pertinent to engineers wishing to enter advanced technology in military guidance, industrial numerical process control, manufacturing process systems.	July 31–Aug 11	$300	
NEW YORK UNIVERSITY			Mr M. Berk, New York University College of Engineering, New York 53
Vacuum Metallurgy Conference—emphasizes new research and advanced engineering problems	June 26–27	$40	
Titanium Metallurgy Conference—emphasizes current research and progress in titanium technology.	Sep 11–12	$20	
Beryllium Conference—discusses current information and progress in beryllium metallurgy.	Sep 7–8	$25	
UNIVERSITY OF PENNSYLVANIA			The Moore School of Electrical Engineering, Special Summer Sessions Office, Univ of Pennsylvania, Philadelphia 4
Logic, Switching Systems and Automata—topics cover computer and information sciences, including general theory of automata, self-producing automata, topological methods in switching theory, and controlled-flow nets.	June 11–24	$250	
New Devices for Amplification & Switching—lectures cover physical theory, construction, behavior and applications of new devices used in amplifiers and switching circuits such as tunnel diodes, superconductivity cryotrons, etc.	June 18–July 1	$250	
JOHNS HOPKINS UNIVERSITY			Dean, School of Engineering, Johns Hopkins University, Baltimore 18
Operations Research and Systems Engineering—covers case studies and expository lectures on operations research, systems engineering, information theory, linear programming, computer theory and programming, etc. First week slanted toward top executives; 2nd week toward technical and managerial personnel.	June 5–16	$300	
UNIVERSITY OF FLORIDA			Dr Robert E. Uhrig, Dept of Nuclear Engineering, Univ of Florida, Gainesville
Nuclear Rocket Propulsion—covers such topics as heat transfer and fluid flow, materials and structural design, nucleonics of rocket reactors, concepts for advanced propulsion, etc.	June 12–23	$150	
COLORADO STATE UNIVERSITY			Director, Institute in Technical and Industrial Communications, Colorado State Univ, Fort Collins, Colo.
Institute in Technical and Industrial Communications—for engineers, scientists, administrators, editors, etc., engaged in preparation of reports, manuals, brochures and other technical communications.	July 10–14	$50	
GEORGIA INSTITUTE OF TECHNOLOGY			Richard Wiegand, director, Engineering Extension Div. Ga. Institute of Tech, Atlanta
Management for Engineers—surveys management theory as it applies to engineering management problems. Slanted to the younger man just entering management responsibility.	July 10–14	$175	
ILLINOIS INSTITUTE OF TECHNOLOGY			Dennis W. Prosser, of Mechanics Dept. Ill. Inst. of Technology Chicago 16, Ill.
Basic Oil Hydraulics—covers basic components in hydraulic circuits. Applicant must have highschool or equivalent.	June 12–23	$100	
OHIO STATE UNIVERSITY			Prof Roy B. McCauley, 190 W 19th Ave, Ohio State Univ, Columbus 10
Fundamentals of Welding Engineering—provides training applicable to structural, piping, pressure-vessel and other products showing inter-relations of welding process, product design, production techniques and quality control.	June 12–23	$200	
CORNELL UNIVERSITY			J. W. Gavett, seminars conductor, Upson Hall, Cornell Univ, Ithaca, N Y
Seminars in Industrial Engineering—student enrolls in one of 9 special seminar groups including engineering administration; systems simulation using digital computers; statistical decision-making; operations management of the smaller company. All students also attend general sessions.	June 13–16	$140	

Control Device Blamed For Mercury-Atlas Failure

CAPE CANAVERAL—The failure to hurl an unmanned Project Mercury space capsule into orbit last week was caused by a preset instrument that translated commands to the Atlas' steering mechanism. The official report states, "Shortly after launch, it was evident that the missile was not responding to roll or pitch commands. The missile was not following its flight path and the dèstruct action was necessary." J. R. Dempsey, manager of Convair-Astronautic, builders of the Atlas, pointed out that this type of failure had never been experienced in 80 previous flights.

Space agency officials and astronauts on the scene could count two credit items:

- Escape device performed as planned.
- Capsule recovery and landing was without difficulty.

MALFUNCTION SHOWED IMMEDIATELY

Although the launching appeared perfect, monitoring signals reported a control malfunction shortly after lift-off; 40 seconds later the decision to destroy the Atlas was made when it had reached an altitude of 16,000 ft. The rockets atop the escape tower pulled the capsule to the left and away from the exploding booster. In one second, the capsule was 200 ft away; it was hoisted an additional 2000 ft before the parachute opened and landed it about 350 yards offshore, seven minutes after launch.

The Atlas mission was to hurl a capsule into a single orbit about 100 miles over the earth. An attempt would then be made to bring the spacecraft to earth within a preplanned recovery area—near Bermuda—after a 110-minute circuit. At the same time, NASA hoped to evaluate capability of its world-wide Mercury network to perform tracking, data-gathering and flight-control functions.

CREWMAN SIMULATOR ABOARD

In addition, the capsule carried an "artificial astronaut"—a 50-lb gray box. The device was designed to use up oxygen, inject carbon dioxide into the capsule's atmosphere, and generally simulate the effect a man would have on the air. It also included equipment to record and play back messages to tracking stations.

The failure would not delay the launching of America's first space man early this month, said Robert Gilruth, director of Project Mercury. Nor, he said, will it prevent the US from placing a man in orbit before the year's end.

SUBORBITAL FLIGHT TO USE REDSTONE

This month's firing is intended to launch an astronaut on a suborbital flight, some 115 miles high and 300 miles downrange, for an elapsed time of about 16 minutes. A Redstone booster, rather than Atlas, is planned to carry the Mercury spacecraft on this mission. ■

Appearance Is Secondary, Designer Tells Paris Seminar

PARIS—To tap the potential of the Common Market, management must integrate industrial design into its overall manufacturing-marketing plans. And this means industrial designers must make external appearance secondary to other considerations, Paul Provost, president of the Belgian Industrial Design Institute, told a seminar here.

He urged anyone hoping to sell a product in the Common Market to take a hard look at the European consumer. The vast market of the "Six" is rich, he pointed out; and the consumer can usually choose from a group of competing products. Often his choice is based on sentiment rather than price. The successful product appeals to his European "intuition."

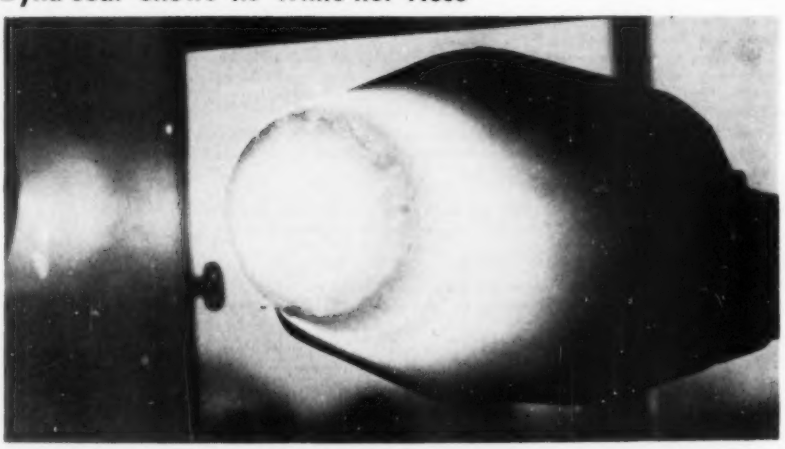
KNOW WHAT MACHINES ARE AVAILABLE

Thus, a designer readying a product for the Common Market, must "consult" the consumer through market studies to understand his preferences, Provost warned. But he emphasized that the designer must not base his design solely on such "consultation." Consumers' attitudes evolve rapidly and it takes at least a year to get a product on the market after design is firm. The designer must then use his own intuition to anticipate consumer preference and not be blinded by the earlier studies.

Probably the soundest start for design, Provost told the seminar, is a study of production machines available to make the product. Coupled with an understanding of the consumer and awareness of the manufacturer's manufacturing plans, this study should point to the one design that suits the product context—manufacturer's production capabilities, marketing plans and anticipated preferences of consumers. This approach relegates external appearance to secondary importance; it frees the designer from a preoccupation that often obscures the bases of a good design.

—Art Erikson, Regional Editor

Dyna-Soar Shows Its White-hot Nose



Ceramic cap that will protect the Air Force, Dyna-Soar man-carrying space vehicle gets its first public showing. The cap (hemispherical forward portion) is here receiving a 3000 to 4000-F blast at Chance-Vought's ramjet test facility. On a space mission, it will take the brunt of reentry heat resulting from 15,000-mph speeds. Dyna-Soar vehicle will be boosted into orbit by rockets, then return on wings.

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POINTS OF VIEW

THE QUESTION:

How Can Our

This month marks the 125th anniversary of the US Patent Office. Since its inception, more than 3 million patents have been granted—but there have been complaints. Here an engineer suggests some improvements that bear consideration.

Samuel R. Frankel is president of his own company, Frankel Engineering Laboratories Inc, vice-president of Electronic Connectors Inc., and treasurer of C N Craley Co—quite a chore for a man still in his thirties. Himself a holder of patents, Frankel has had experience in dealing with the system.

PATENT PROBLEMS

A combined reprint of 19 articles covering the patent laws both here and abroad and how they operate for inventors and corporations. Send $1.50, for each copy, to **Reader Service Dept, Product Engineering, 330 W 42nd St, New York 36.**

Recent months have produced much criticism of America's present patent system, both in technical periodicals and in government hearings. There have been complaints about the fairness of its operation and how much progress in science and the useful arts it has fostered. The basis of our patent law—Art I, Sec 8 of the United States Constitution—treats these two as cause and effect, or means and goal, saying its purpose is "to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

The progress of science in our country today is not what it ought to be, at least in part, because the patent system no longer functions equitably. There is no longer secured to inventors the exclusive right to their inventions, even for limited times. The patent equity I propose concerns equity not only in the sense of fairness but also in the sense of a property right, and would require an extension of the patent law to secure that right.

The individual inventor, in the majority of cases, no longer reaps the benefit of his creativity. The rise of the corporate structure and complexity of technology has brought this about. In nearly every corporation, a scientist or engineer accepting employment must sign a patent agreement assigning to the employer-corporation all rights in any invention which might prove patentable made by him at least during the tenure of his employment. In addition, inventions made by those not required to sign such an agreement may be subject to a "shop right."

Several reasons have been cited to support the fairness of this arrangement. Large corporations supply the extensive facilities needed to advance our sophisticated technology; these are very costly and therefore, it is argued, the corporation is entitled to ownership rights in patents resulting from use of these facilities. This same argument may be used to show how little freedom of conduct the individual has when signing the required patent agreement. Creative people must seek employment in corporations where they can secure access to the tools of their creativity. They do not, then, sign away their rights in their inventions from truly free choice, but rather because there is no actual alternative. What is needed is a system that makes sure a firm will receive a return on its investment, both in facilities and personnel training, before being required to compensate an inventor for a particular invention.

Employer's point of view

Employers argue that perhaps one patent in twenty is a commercial success; and that, therefore, they cannot afford to reward all inventors. The answer to this is a royalty which is proportionate always to the success of

Patent System Be Improved?

the invention. It should not burden the employer; he should pay only when he is reaping a direct benefit.

It has also been said that inventions these days stem from company know-how and group effort, and that, therefore, an invention coming out of a lab or research group is the product of the organization and belongs to the organization rather than to any individual. This reason is among those advanced as justification for abolishing the patent system entirely. I do not agree with either the reasoning or the solution. The seed of an idea comes from an individual, and the additional ideas necessary to make it work come from individuals. Although several may contribute to an invention, the result is the sum of their individual contributions and not a homogeneous "group contribution." With some diligence the truly contributive individuals can be recognized and the rights ought to go to them, whether as inventors or as co-inventors. We need not abolish the patent system for lack of inventors. We must only make sure that the true inventors reap the reward intended by the patent system. There is a need for legislative implementation of the Constitution's intent to reward inventors.

The new plan

To achieve this end without causing a hardship to employers, I have devised the following "5-patent Rule." If enacted, it would set up a system of rewards payable as a royalty of some percent to be decided upon by the legislature, to be given by employers to qualified inventors for centain inventions. In order to qualify, an inventor must have already been inventor or co-inventor of five issued patents. This qualification immediately reduces the inventors covered to about 5% of all individual inventors, and ensures that rewards would go only to those of proved creativity. Further, it would ensure that the firm paying the royalty had already benefited either from this inventor's previous inventions or from his past experience. In addition, because today's recent graduates among scientists and engineers receive large salaries, but their more experienced counterparts do not receive commensurately higher salaries, this rule would tend to rectify the inequity of compensation that now exists.

Royalties to benefit employer and employee

Once having qualified by obtaining five patents, an inventor would not receive any royalty from his employer under this plan until he contributes an invention which forms the basis for a branch of business in which the employer was not formerly engaged. For example, suppose a 5-patent inventor, while working on the design of an improvement on one of his company's paper machines, devises a new and patentable vibration transducer to assist him. That vibration transducer ought to belong to the paper-machinery company only if it produced it and pays the inventor a royalty on it. If it does not choose to produce it, the invention ought to belong exclusively to the inventor, with the right then to sell or license it to anyone he chooses.

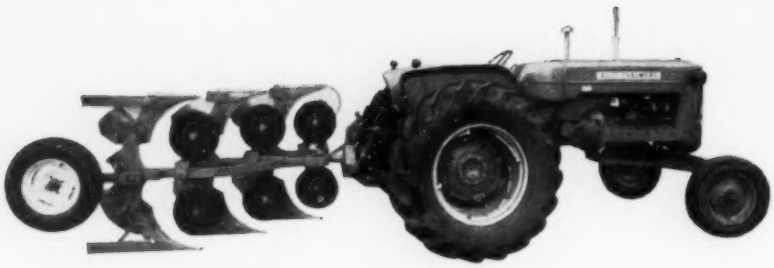
It seems to me that inventors of proved creativity have often put their employers in a new and lucrative business without being commensurately remunerated. It is true that an employee owes all allegiance to his employer, and if hired for his creative ability will presumably be paid accordingly and expected to contribute to the advancement of all products, machines, processes, etc., associated with the employer's business or on which research has been started for that business. However, this allegiance should not have to extend to all products from an inventive mind, nor should an employer be the exclusive gainer from an extraneous invention of an employee. The shop right or patent assignment is necessary for improvements on the employer's existing products, methods or machinery. It is an undeserved windfall for products divorced from its industry.

Effects of this new patent plan

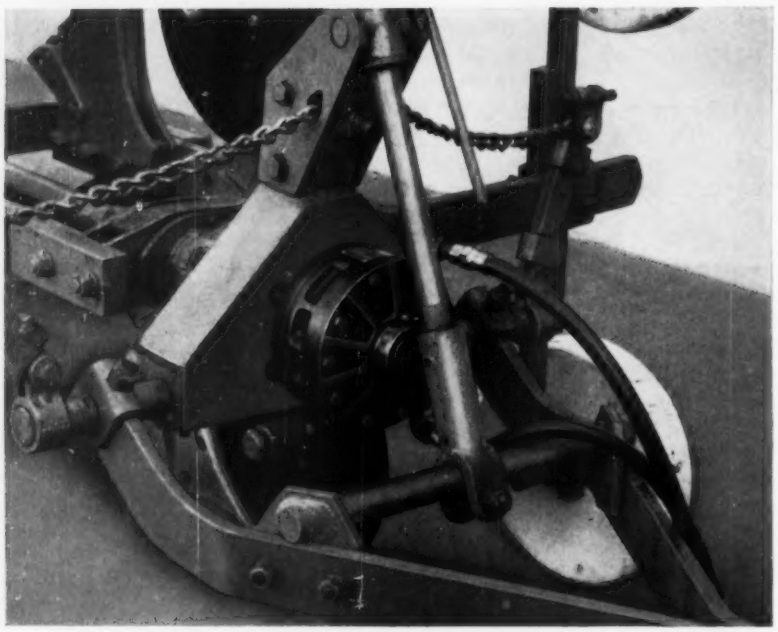
This new system should have several salutary effects which bear consideration:

- It would stimulate creative efforts by inventive minds and thereby add to the national security and welfare.
- It would decrease suppression of meritorious inventions, the inventor having the right to exploit those inventions not exploited by his employer.
- It would reduce the load of unmeritorious applications going through the Patent Office; firms would be unwilling to qualify men for a possible royalty situation unless they deserved to be.
- It would reduce patent skulduggery, whereby names of real inventors are left out or names of noninventors are inserted in patent applications for some extrinsic reason. Inventors would have more reason to be jealous of their rights in all patents.
- It would minimize job-hopping for salary increases, thereby stabilizing the work force and speeding the completion of important projects.

Although this proposal would affect only a small percentage of scientific personnel, it would create a goal toward which all could strive: raising the national level, in quality and quantity, of creative output. The proposal may be a departure from actual practice, but it is in concert with the original Constitutional intent that inventors be rewarded with more than a humiliating dollar bill and a pat on the back.



New Allis-Chalmers spinner plow actuated by Houdaille's HydRoAc



Houdaille's versatile new HydRoAc Rotary Actuators found immediate application on this Two-way Moldboard Plow built by Allis-Chalmers. Mounted on the end of the rotatable plow shaft, the HydRoAc unit provides a compact, efficient method of "spinning" the plow bottoms at the end of each furrow.

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READER TO EDITOR

Old-Fashioned Reliability

To the Editor:

Your editorial ("3-D Testing Mar. 20, p 55) is thought-provoking. You quote an "R & D" director as saying "we need a new language and a new approach." It is doubtful that we need a new language. It is the habit of workers in a "changed" field to invent a "jargon" understood only by themselves, for reasons explicable perhaps by intellectual snobbishness.

I suspect that we are all suffering from a too rigid application of Aristotelean logic. Single-valued logic and the theorem of the excluded middle simply will not do the job. Yet most of our computers and testing methods are based upon those very things. To every question submitted to a computer, the computer renders, basically, a yes or no answer. It can't give such answers as gray, it must say black or white. It can't say "perhaps."

Now this is not to deny the computer. It does a marvelous job on problems involving single-valued logic and the theorem of the excluded middle. For modern problems, we need to develop the art of "network" thinking. Network thinking may be described as the ability to consider the effect of a whole flock of variables, some of which are increasing, some are decreasing some are cycling others are strays.

Perhaps a little more intuition is needed. Sometimes in the effort to make things longer lived, or more reliable, we defeat the very purpose we have in mind. Adding a lubrication system to a bearing may, in many cases, make the bearing plus system less reliable than an unlubricated bearing. I don't know whether you grew up with the Model T Ford. It was a horrible thing, but it ran. I shudder to think of what would happen to a late-model car if it were submitted to the abuse that Model T took. The stuff we fed them for gasoline varied from light fuel oil to casing-head gas that would evaporate from the fuel tank on a hot day. I have, in an emergency, lined a connecting-rod bearing with leather. I have even filtered bacon grease and used it in the crankcase in an emergency. Through all this the old Model T would run. It was reliable. It did not run very well, it did not have flashy performance, but it ran.

From the standpoint of reliability it would appear that we are now getting some hard-headed skeptics into testing. When we buy an appliance, an automatic pencil, or an automobile or a drink mixer, if it works, and continues to work, economically and without too much trouble, we don't care who designed it. Nor does it matter whether the stuff was made of platinum or gold, or cow chips, so long as it works.

There is still a lot to be said for the old-fashioned virtues of reliability, integrity and quality. We are with you on these

—W H Sayler
Specialty Sales Co
Salt Lake City, Utah

• My first Model T cost me $15 second-hand and was re-sold three months later

for the same amount. My second was converted to a "racer" by inverting the spring shackles and applying a Sears Roebuck body with detachable fenders. It would hold four, properly stacked, in a clinch—and did. And, like an old slow-speed diesel, it ran on many things, including high-test gas drained from tank cars and filtered through tracing cloth. Lube oil from the same source was filtered through gunny sacking. And the car could be parked by running the nose in to the curb, then lifting the torpedo tail over. That tail was better than any bumper in keeping following cars at a respectable (and respectful) distance. It worked fine, too, until a youngster borrowed it one night and tried to go between a tree. —EJT

Correction

In the April 3 Design File, "Checklist for Planetary Gear Sets," p 60, the planet gears in the example for Test 3, Case 1, can be spaced at even 120 deg intervals. The rule is: If $N_s + N_r$ is evenly divisible by the number of planets, the planets can be evenly spaced around the sun gear.

There is an easier way to work Case II. Place the first planet at an angle $360 [a/ (N_s + N_r)]$, where a is a whole number that makes spacing most nearly ideal: In the example, $a = 49$. Test 4 should read: "They will if the major diameters adhere to this limitation: $(2M_p + m_s)$ is less than $< m_r$ by a safety clearance of 1/32 in. more than maximum tolerances." —Ed

COMING EVENTS

MAY

9-11 . . . . Western Joint Computer Conference, Ambassador Hotel, Los Angeles

9-11 . . . . Institute of Radio Engineers, 1961 Electronic Components Conference Jack Tar Hotel, San Francisco

10-12 . . . . Society for Experimental Stress Analysis, Spring Meeting, Benjamin Franklin Hotel, Philadelphia

14-17 . . . . National Fluid Power Association, 1961 Spring Meeting, The Greenbrier, White Sulphur Springs, WVa

22-25 . . . . American Society of Mechanical Engineers, Design Engineering Conference & Show, Cobo Hall, Detroit

22-26 . . . . American Society of Tool & Manufacturing Engineers, 1961 Convention, Statler Hilton Hotel, NYC

JUNE

4-7 . . . . American Gear Manufacturers Assn, Annual Meeting, The Homestead, Hot Springs, Va

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FOR YOUR INFORMATION (personal)

Make-your-own fuel cell

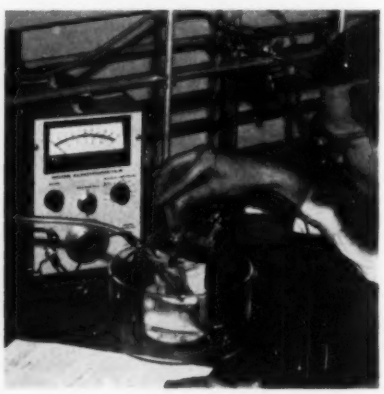
Instructions for building a demonstration fuel cell and a transistor radio to go with it are contained in an 8-page educational booklet prepared by Esso Research & Engineering.

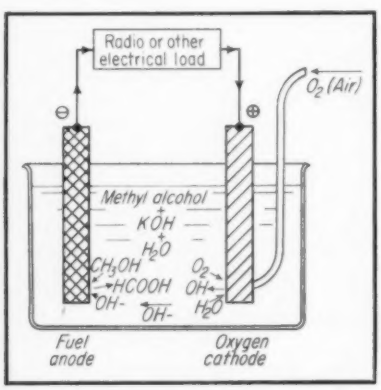
Using materials readily available from scientific and radio supply houses, a cell like the one shown here can be built for about $10; the radio for about $8—and the booklet tells exactly where to get supplies, gives diagrams and parts lists.

The fuel cell electrodes are catalyst-coated nickel screen—a platinum coating for the fuel electrode and silver coating for the oxygen electrode. The fuel is methyl alcohol; the electrolyte, potassium hydroxide.

The radio receiver, assembled from standard parts, includes 2 transistors, a diode tuning capacitor and antenna coil.

Copies of the booklet are free from Esso R & E, PO Box 45, Linden, NJ.





IN FUEL CELL, oxygen is fed to cathode where it reacts with water in the electrolyte, producing negatively-charged hydroxyl (OH-) ions and resulting in an electron deficiency or demand at the cathode. At the anode, the fuel (methyl alcohol) reacts with the hydroxyl ions, producing formic acid (HCOOH) and free electrons. These flow through the external circuit to the cathode.

Electrostatic "push" to beat gravity?

Can gravity be overcome by developing electrical charges of like sign on a space ship and the ground so they will repel each other?

It wouldn't work on earth—but it might work on the moon and other celestial bodies where no atmosphere is present, says John C. Cook of Southwest Research Institute.

In developing such electrical charges, he says, a large amount of electrical energy must be forced into the "capacitance" of the system. But, during an ascent through a gravitational system, a portion of this stored electrical energy would be transformed into gravitational potential energy. In the subsequent descent, this same energy could be returned to the electric field without loss. Furthermore, it could be transformed back and forth again and again, in innumerable round trips through the gravitational systems of all the planets visited. The spaceship would operate something like a balloon, rising or descending at the will of the passengers by means of small adjustments of its electric charge.

He admits, of course, that in practical application such accessory considerations as incidental electrical losses may prove serious. Nevertheless, he says, "electrostatic lift remains interesting as a possible means of efficient liaison with small airless bodies, and as a presently feasible technique incorporating the main properties of an ideal space propulsion system. Fully reversible, it requires almost no dissipation of either energy or mass in traversing the strong gravitational field of a planet." —ARG

PRODUCT ENGINEERING HORIZONS

May 8, 1961

The Rut of Complacency

College enrollments are beginning to zoom; science enrollments are too. But not engineering. The relatively small percentage of engineering enrollments is still slipping, and the mortality still stands at around half. In the Soviet Union, engineers form almost half the enrollments and the losses are only 9% from day-classes, 20% from evening ones.

Why?

Because, in the rising countries, engineering is recognized as a preferred and necessary career, by government, schools and people. Students are encouraged to try for engineering first. There is fierce competition for every engineering-college opening, fiercer competition to stay in it. Even the professors are required to take competitive examinations every five years; there is no tenure. Added education is recognized by increased income and prestige; accomlishment is recognized by bonus and kudo.

Our problem begins, not in the colleges, but in the secondary schools, many of which welter in inertia. As one alert parent told his high-school principal, "You're in a complacent rut. Your teachers are professional babysitters, not expected to stretch anyone's mind, just to provide him with certain manual and social skills. Thinking is frowned upon."

He was stared down, of course. And perhaps he was exaggerating. But how many children do learn to think? How many are encouraged to reach out? How many teachers have been slapped down as radicals or pinks by boards or parents because they encouraged students to reach out?

There are in this country about 22,000 high schools, down by rural consolidations from a peak of 30,000. The larger the school, the larger its faculty, the more branches of knowledge theoretically represented, the greater the specialization.

But nowhere is there any specialization in engineering, nowhere is there any inclination toward, or interest in, engineering as a career. The student who turns in the direction of engineering does so because of family or personal interest.

Except in 785 schools. In these, there are chapters of JETS—the Junior Engineering Technical Society. They are essentially engineering clubs, somewhat like the more-familiar Science Clubs, but undertaking engineering projects with the help of a teacher and local professional engineers. Some 24,000 high-school boys are members this year, in 48 of the 50 states. There'd be many more, but the organization's growth is limited by available funds. Teachers find it helpful in interesting students in current events and helping them to understand our increasingly technological world. They find the instructional information provided in fortnightly "academic units" is also helpful in updating their curricula—at least so 65% of them say.

Effects? Some 90% of JETS members go on to college, 67% as engineering students. Both percentages are far above national averages. And a far greater percentage complete their courses for degrees.

At the local level, chapters are sponsored by nearby plants, by chapters of interested national societies (notably NSPE and ASTME), and by state universities who also provide advisors. The entire program has been financed principally by donations from industry. For details, see the story in the *Saturday Evening Post* for March 4, 1961, or write to Richard Fallon, executive director, Box 589, East Lansing, Mich.

F. J. Langeman

simpler acceleration analysis of

LOW-COMPLEXITY MECHANISMS

When driven in a certain way, they lose their complexity and become suitable for the analysis method given here. Author also supplies two sample problems that illustrate the step-by-step analysis procedure.

J HIRSCHHORN, *associate professor of mechanical engineering*
University of New South Wales, Sydney, Australia

Kinematically, mechanisms can be classed as simple, or complex. The analysis procedure given here, an offshoot of the relative-acceleration method, applies to mechanisms of "low complexity"—their complexity depends on which link does the driving. Here is how the two categories compare:

A mechanism is considered kinematically simple if its acceleration analysis can be performed by a step-by-step application and graphic solution of the motion-transfer vector equation

$$ {}_{P}a_{Q} = a_{P} + a_{Q} $$

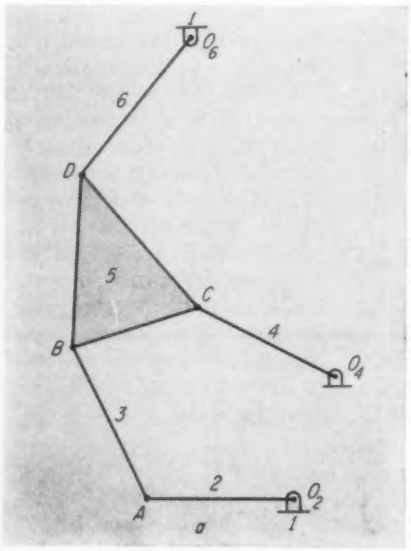
or

$$ {}_{n}a_{Q} + {}_{t}a_{Q} = ({}_{n}a_{P} + {}_{t}a_{P}) + ({}_{n}a_{QP} + {}_{t}a_{QP}) $$

or combined, if necessary, with the acceleration-image procedure. Note the important fact that the equation can only be solved if the path curvatures of P and Q are determinable by inspection. Also note that the normal acceleration component of any point on a constrained link is a function of its speed and the geometry of the constraints—it is independent of the link's angular acceleration; this is shown by the following relationship:

$$ {}_{n}a_{P} = v^{2}_{P}/\rho_{P} $$

and its direction is toward the center of curvature of the path.



1 Low-complexity mechanism with ternary links

A mechanism is considered kinematically complex if the path curvatures of essential motion-transfer points cannot be determined by inspection. A characteristic feature of such mechanisms is a multi-paired floating link, an element which forms kinematic pairs with not less than three other moving links, but not with the frame. The degree of complexity may be "low" or "high":

A low-complexity mechanism is one which is kinematically complex when driven by one link, but simple when driven by another. By contrast, a high-complexity mechanism remains complex no matter which link is used for the motion input.

Fig 1 illustrates diagrammatically a mechanism of the low-degree-of-complexity kind: only two of the attached links, namely 4 and 6, are required for a complete constraint of the ternary (triple-paired) link 5. And when driven by link 2, the mechanism is kinematically complex because the path curvature of B is not known and consequently the vector equation

$$ {}_{n}a_{B} + {}_{t}a_{B} = ({}_{n}a_{A} + {}_{t}a_{A}) + ({}_{n}a_{BA} + {}_{t}a_{BA}) \qquad (1) $$

cannot be solved.

However, when driven by either link 4 or 6, the mechanism is kinematically simple. For instance, with 6 as alternative input link, the acceleration analysis would proceed as follows:

Step 1: Construct a_C, basing the construction on:

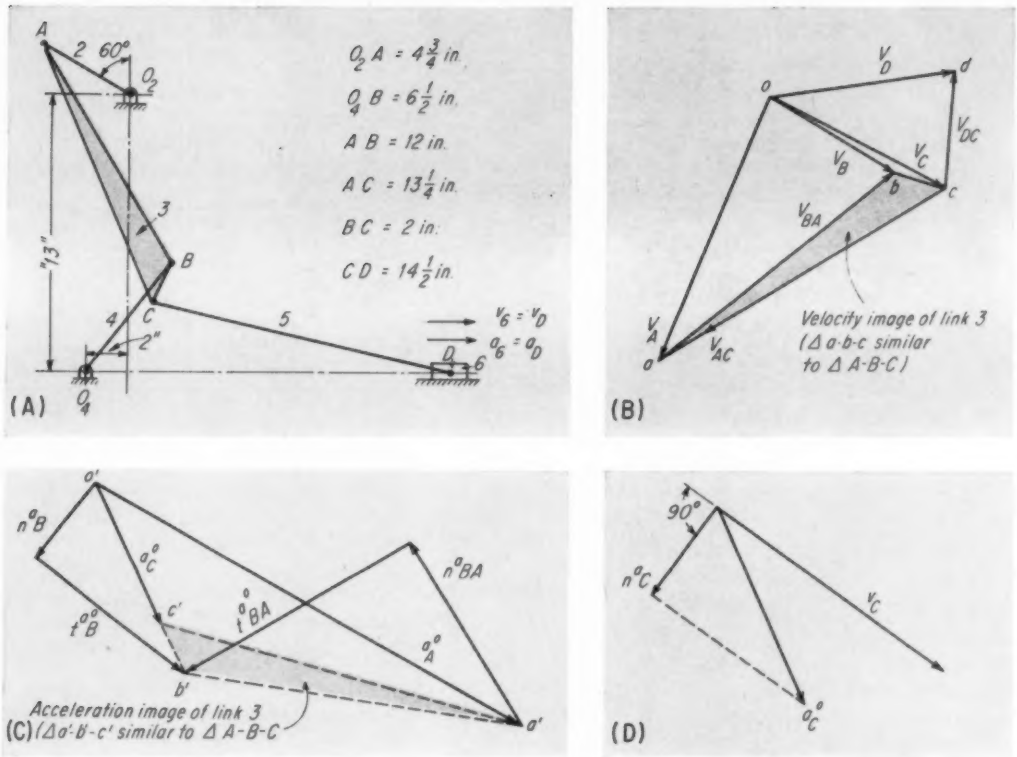
$$ {}_{n}a_{C} + {}_{t}a_{C} = ({}_{n}a_{D} + {}_{t}a_{D}) + ({}_{n}a_{CD} + {}_{t}a_{CD}) \qquad (2) $$

Step 2: Construct a_B by means of the acceleration image of link 5

Step 3: Construct a_A, using

$$ {}_{Q}a_{A} + {}_{t}a_{A} = a_{B} + ({}_{n}a_{AB} + {}_{t}a_{AB}) \qquad (3) $$

The acceleration of B, determined in Step 2, can be resolved graphically into its components ${}_{n}a_{B}$ and ${}_{t}a_{B}$, the former normal, and the latter parallel to the velocity vector v_B. From what was said before about the nature of the normal accelerations it is clear that, as long as the


(A)
(B)
(C) Acceleration image of link 3 (Δ a'-b'-c' similar to Δ A-B-C
(D)
(E)
Velocity image of link 3 (Δ a-b-c similar to Δ A-B-C)
O2A = 4 3/4 in.
O4B = 6 1/2 in.
AB = 12 in.
AC = 13 1/4 in.
BC = 2 in.
CD = 14 1/2 in.

2 (A) Configuration diagram

(B) Velocity diagram

(C) Auxiliary acceleration diagram

(D) Determination of normal acceleration component

(E) Actual acceleration diagram

auxiliary acceleration diagram is based on the actual velocities, the construction yields the true value of $_na_B$ required for the solution of original Eq (1). When constructing the auxiliary acceleration diagram it is immaterial what angular acceleration is assigned to the alternative input link. Generally this is taken as zero. Once $_na_B$ is known, the actual acceleration diagram can be constructed, starting with the prescribed acceleration of the true input link.

The application of this approach to practical problems is demonstrated in the following examples.

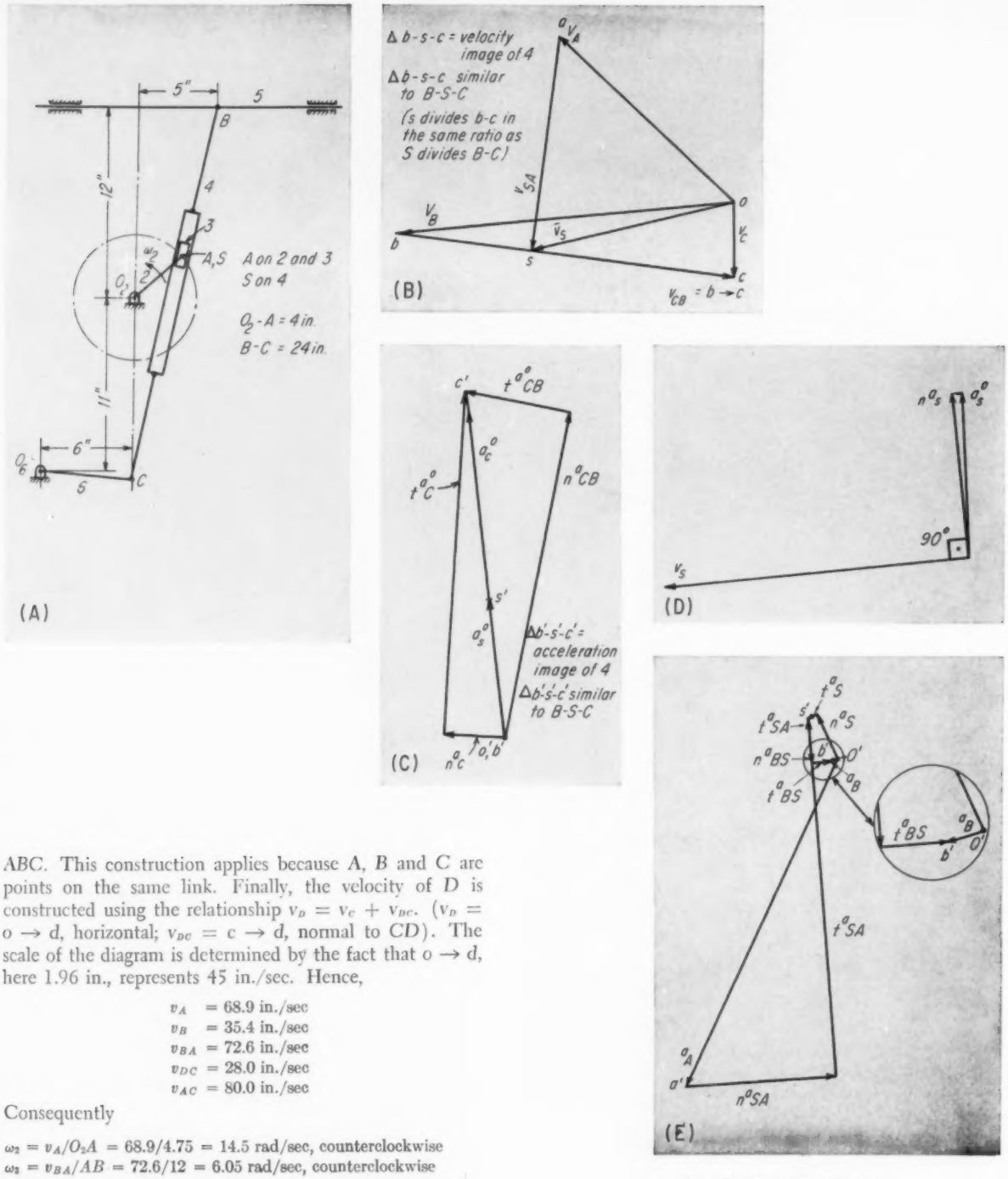
EXAMPLE 1

The slider, link 6, of the Atkinson engine mechanism, Fig 2 (A), has an instantaneous velocity of 45 in./sec, and an acceleration of 400 in./sec^2 in the direction shown. Determine ω_2, ω_3, α_2 and α_3.

Solution:

With the slider driving, the mechanism is complex because ρ_C is not known and $_na_C$ cannot be computed. However, if link 2 is considered as an alternative input link, the mechanism is simple, and $_na_C$ can be determined as follows:

The velocity diagram, Fig 2 (B), is constructed starting with v_A, represented by the vector $o \rightarrow a$ (normal to O_2A) of arbitrary length, here 3 in. The velocity of B follows from $v_B = v_A + v_{BA}$. ($v_B = o \rightarrow b$, normal to O_4B; $v_{BA} = a \rightarrow b$, normal to AB). $v_C = o \rightarrow c$, is determined by the image method, by making triangle abc similar to triangle



3 (A) Configuration diagram

(B) Velocity diagram

(C) Auxiliary acceleration diagram

(D) Determination of normal acceleration component

(E) Actual acceleration diagram

ABC. This construction applies because A, B and C are points on the same link. Finally, the velocity of D is constructed using the relationship $v_D = v_C + v_{DC}$. (v_D = o → d, horizontal; v_{DC} = c → d, normal to CD). The scale of the diagram is determined by the fact that o → d, here 1.96 in., represents 45 in./sec. Hence,

v_A = 68.9 in./sec
v_B = 35.4 in./sec
v_{BA} = 72.6 in./sec
v_{DC} = 28.0 in./sec
v_{AC} = 80.0 in./sec

Consequently

$\omega_2 = v_A/O_2A = 68.9/4.75 = 14.5$ rad/sec, counterclockwise
$\omega_3 = v_{BA}/AB = 72.6/12 = 6.05$ rad/sec, counterclockwise

Now the auxiliary acceleration diagram, Fig 2 (C), can be constructed, assuming $\alpha_2 = O$. It is started with the acceleration of A represented by the vector o' → a', drawn to some suitable scale. ($_na_A = v^2_A/O_2A$, directed from A to O_2; $_ta^o_A = (O_2A)$; $\alpha_2^o = O$. The acceleration of B is constructed with the aid of the relation

$$_na_B + {}_ta^0_B = a^0_A + ({}_na_{BA} + {}_ta^0_{BA})$$

($_na_B = v^2_B/O_4B$, directed from B to O_4; $_ta_B$ normal to O_4B; $_na_{BA} = v^2_{BA}/AB$, directed from B to A; $_ta_{BA}$ normal to AB). The acceleration of C, a_c^o = o' → c' is constructed by

SYMBOLS

a_P — Absolute acceleration of point P
$_na_P$ — Normal component of a_P (perpendicular to v_P)
$_ta_P$ — Tangential component of a_P (in line with v_P)
a_{QP} — Acceleration of point Q relative to point P
$_na_{QP}$ — Normal component of a_{QP} (directed from Q to P)
$_ta_{QP}$ — Tangential component of a_{QP} (perpendicular to $_PQ$)
v_P — Absolute velocity of point P
v_{QP} — Velocity of point Q relative to point P (perpendicular to PQ)
ρ_P — Path-radius of curvature of P
α_s — Absolute angular acceleration of link s
ω_s — Absolute angular velocity of link s
a^0 — Auxiliary accelerations based on zero alternative input acceleration (see Fig 2, 3).

the image method, by making triangle $a'b'c'$ similar to triangle ABC. This makes it possible to determine the magnitude and direction of $_na_C$, as shown in Fig 2 (D) for clarity.

Since a_D is given and $_na_C$ is now known, the true acceleration diagram, Fig 2 (E), can be constructed, using the relationships

$$_na_C + {}_ta_C = a_D + (_na_{CD} + {}_ta_{CD})$$

and

$$_na_A + {}_ta_A = a_C + (_na_{AC} + {}_ta_{AC})$$

This acceleration diagram yields

$$_ta_A = 390 \text{ in./sec}^2$$
$$_ta_{AC} = 131 \text{ in./sec}^2$$

Consequently the true angular accelerations are

$\alpha_2 = {}_ta_A/O_2A = 390/4.75 = 82$ rad/sec², counterclockwise
$\alpha_3 = {}_ta_{AC}/CA = 131/13.25 = 9.9$ rad/sec², counterclockwise

If desired, the acceleration diagram can be completed as shown in broken lines. A good check on the accuracy of the working arises from the fact that b', determined by the image method, should lie on the line drawn through the end-point of $_na_B$, normal to O_4B.

EXAMPLE 2

The crank, link 2, of the modified shaper mechanism, Fig 3 (A), revolves at a constant angular velocity of $\omega_2 = 5$ rad/sec, counterclockwise. Determine v_B and a_B.

Solution:

With link 2 driving, the mechanism is complex because the path curvature of the point S on link 4 is unknown. However, if link 5 (point B) is used for the alternative motion input, the mechanism becomes kinematically simple.

Fig 3 (B) is the velocity diagram for the mechanism. Its construction is started with v_B, represented by the horizontal vector $o \rightarrow b$, of an arbitrarily assumed length, here 4 in. The velocity of C follows from $v_C = v_B + v_{CB}$, ($v_C = o \rightarrow c$, normal to O_6C; $v_{CB} = b \rightarrow c$, normal to BC). Next, $v_S = o \rightarrow s$, is determined by the image method, by making the line segment bsc similar to BSC. Finally, the velocity of A is constructed using the relation $v_A = v_S + v_{AS}$. $v_A = o \rightarrow a$, normal to O_2A; $v_{AS} = s \rightarrow a$, parallel to the direction of sliding BC. The scale of the diagram follows from the fact that $o \rightarrow a$, here 2.86 in., represents the known velocity $v_A = (O_2A)\ \omega_2 = 20$ in./sec. The diagram yields:

$v_C = 6.1$ in./sec
$v_{CB} = 27.9$ in./sec
$v_{SB} = 11.1$ in./sec
$v_{SA} = 18.0$ in./sec
$\omega_4 = 1.6$ rad/sec, counterclockwise
$v_B = 27.9$ in./sec, directed to the left

Fig 3 (C) is the auxiliary acceleration diagram, drawn to a suitable scale and based on the arbitrarily assumed acceleration $a_B = O$. The acceleration of C is constructed using the relation

$$_na_C + {}_ta^0_C = a^0_B + (_na_{CB} + {}_ta^0_{CB})$$

($_na_C = v^2_C/O_6C$, directed from C to O_6; $_ta_C$ normal to O_6C; $a^e_B = O$; $_na_{CB} = v^2_{CB}/BC$, directed from C to B; $_ta_{CB}$ normal to BC). The acceleration of S, $a^e_S = o' \rightarrow s'$, is constructed by the image method, by making the line segment $b's'c'$ similar to BSC. Fig 3 (D) shows the construction of the required component $_na_S$.

The final step in the analysis consists of the construction of the actual acceleration diagram, Fig 3 (E), using first the relation

$$_na_S + {}_ta_S = a_A + (_na_{SA} + {}_ta_{SA})$$

which yields a_S. [In this case $a_A = {}_na_A$, because ω_2 is constant ($_ta_A = 0$). Also, because the motion-transfer point A on link 3 moves relative to the coincident motion-transfer point S on link 4 in a rectilinear path, the vector $_na_{SA}$ is equal to the Coriolis acceleration of the two points. Its magnitude is 2 (ω_4) v_{SA}, and its direction is obtained by turning v_{SA} through 90° in the sense of ω_4].

The acceleration diagram is completed by using the relation

$$a_B = a_S + (_na_{BS} + {}_ta_{BS})$$

The diagram yields $a_B = 2.4$ in./sec², directed to the left.

EDITOR'S NOTE: For additional information on design of four-bar linkage mechanisms see:

When Linkages Need Harmonic Analysis, Mar 6 '61, p 47—Gives tabular solution to complex Fourier-series equations and thus simplifies harmonic analysis for efficient design of crank-and-rocker mechanisms.

Special Chart Leads You to Four-bar Linkage Proportions, Sep 19 '60, p 76—With two points given, this handy chart quickly locates the other two. You find the proportions of all four bars without cumbersome mathematics or graphical methods.

5 Graphical Methods for Designing Four-bar Linkages, Apr 4 '60, p 37—Gives roundup of methods used to synthesize four-bar linkages, including the point position reduction method developed by Kurt Hain.

Robert's Law Helps You Find Alternative Four-bar Linkages, Oct 27 '58, p 54—Method of similar triangles is expanded by author's method of laying off the link lengths along a straight line.

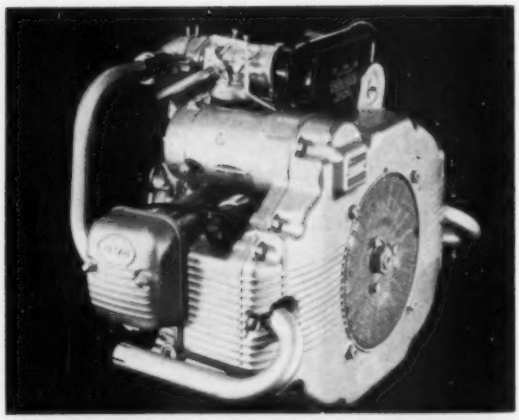
Linkage Design Techniques, Dec '54, p 133—Gives comparison of 4 methods—two approximate and two exact—for construction and design of four-bar linkages.

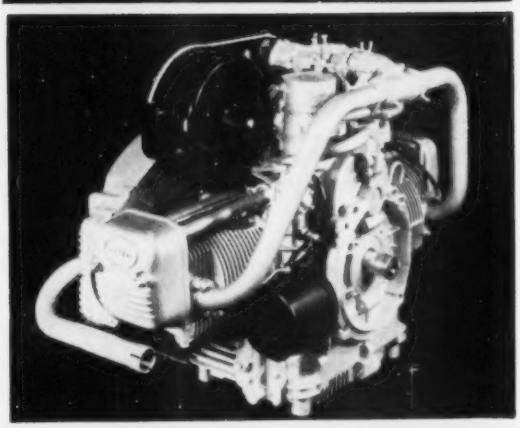
Linkage Layouts by Mathematical Analysis, Aug '55, p 165—Shows how to obtain a specified relationship between input and output for a differential by determining number and types of links needed.

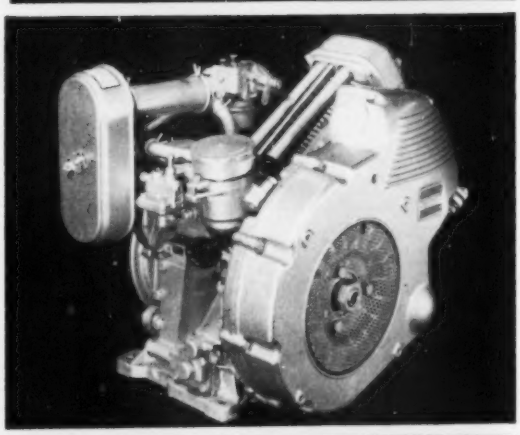
—Frederick Marich

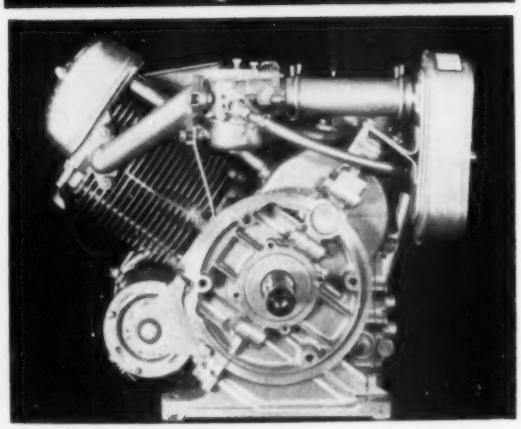
Engines Tailored for Design Needs

Wide range of options permits users to order engine which fills design requirements. Double-duty parts simplify production, reduce stock of replacement parts.







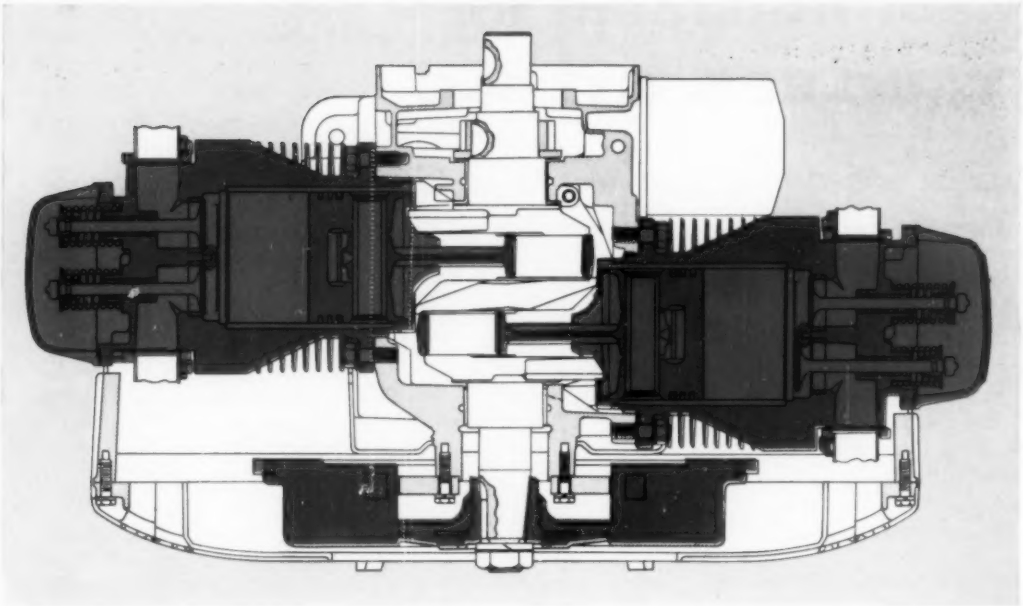


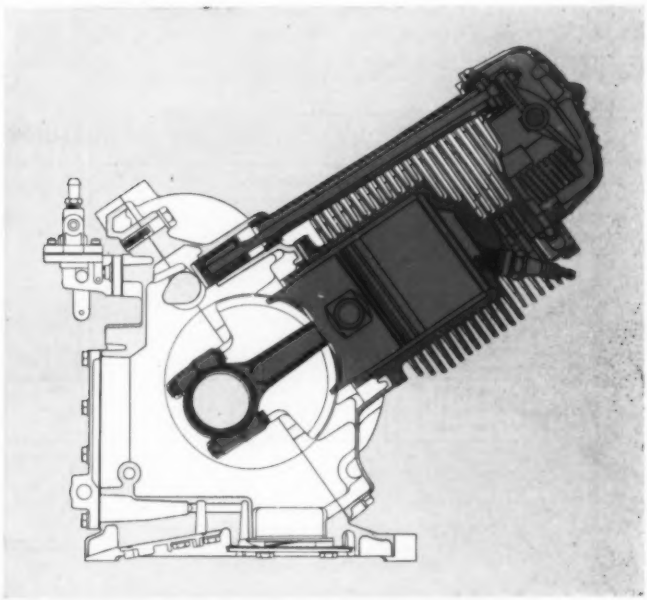
POWER PACKAGES must occupy the minimum volume to be suitable for as many different types of machines and vehicles as possible. Achieving such compactness without sacrificing service accessibility generally requires the engine to be "self-covering." Yet without an exterior housing, gasoline engines can easily look like a hit-or-miss assortment of subassemblies, mechanical parts, nuts and bolts. This has been avoided in the OMC line of 9- and 18-hp aluminum engines by extending such elements as the cooling shrouds and using them as mounting panels for related components. Unity with adjacent engine components such as the rocker-box covers is had with decorative ribbing that echoes the cooling fins on the cylinders. Intake and exhaust lines also help give the 2-cyl model an over-all look of integration.

OPTIONAL MODIFICATIONS of the basic engine enable user to tailor his power package to the job. The following variations are available: carburetion systems to use four different fuels, four valve and valve-seat combinations, four main and rod-end bearing options, three types of air cleaners, six different crankshaft modifications, five starter types, six kinds of engine-speed control, four engine shrouds. In addition, a wide range of gear reductions, fuel tanks, instrument panels, ignition systems and engine mountings are applicable. For special climatic or environmental conditions, fungus-proofing, radio shielding, carburetor heating, reverse-flow cooling (18-hp model) and super-quiet mufflers can be specified.

PS . . . First two models of die-cast aluminum engines are forerunners of a family that will range from 2½ to 75 hp. Future line, available to manufacturers of industrial equipment, machinery and vehicles, will include aircooled and watercooled, 2- and 4-cycle models.

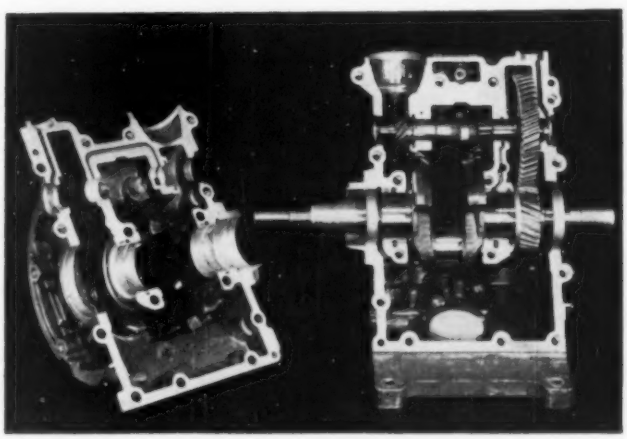
The initial engines are (1) 9 hp, 4 cycle single-cyl, aircooled; (2) 18 hp, 4 cycle, 2-cyl, aircooled. Produced by Outboard Marine Corp, Waukegan, Ill., and marketed by the company's OMC Engines and Equipment Div.





RELATIONSHIP of 1- and 2-cyl engines is indicated by the colored parts common to both. Of the total of 238 parts in 2-cyl model, 150 are interchangeable with the single-cyl unit. General design principles of both units are identical, and future multicylinder engines will employ parts and principles used in initial models.

Aircooled overhead-valve cylinders are die-cast in a single piece, eliminating separate cylinder heads, head bolts and gaskets. Cast iron cylinder liners and valve seats are cast in place, but valve guides are removable. Cam-ground aluminum pistons and forged connecting rods with steel-backed babbitt bearing inserts are used. Valve rockers are actuated by pushrods and cam followers are operated by a camshaft in the crankcase. The gear-driven camshaft also operates cam-drive fuel pump and gear-driven timer and oil pump. Positive-displacement gear pump delivers oil at 40 psi to all bearing surfaces. Oil system contains a strainer, filter, bypass valve and pressure switch. Die-cast crankcase is split in half to simplify maintenance and casting. Two tapered dowel pins are used to align the castings, which are assembled without gaskets. A liquid mastic is brushed on the milled crankcase edges to provide oiltight seal.



best heat treatment for PH STAINLESS STEELS

When specifying a hardening treatment for 17-PH and PH 15-7 Mo, choose the one best suited to your design needs. These property data, plus details on the strengthening steps, will help.

D C LUDWIGSON, *principal metallurgist, Battelle Memorial Institute*

For high-strength structural parts subject to corrosion, 17-7 PH and 15-7 Mo steels are becoming a practical answer. Experience shows their higher cost is often cancelled out by the ease with which they can be formed after the annealing. Also, they can be hardened to tensile strengths over 200,000 psi—without drastic quenches that cause distortion.

There PH (precipitation hardenable) steels often need heat treatments more complex than for the normal hardenable steels. In return, however, they offer superior resistance to both corrosion and wear. And the aging step gives an extra boost to strength. In general, the final properties desired, and the final form of the manufactured part, will dictate which heat treatment to specify.

4-step hardening

The chart shows each hardening sequence begins with an anneal and ends with the appropriate aging step:

1. Solution-anneal. In this mill-supplied form ("condition A"), these steels are austenitic (like the 18-8 stainless steels). Hence they are soft and easily fabricated—with typical elongation of 35% and yield strengths about 50,000 psi; can be bent, stamped, drawn and spun like the 18-8 steels, but they work-harden slightly faster.

SIX PH HARDENING SEQUENCES

THE HEAT TREATMENT				THE TENSILE PROPERTIES					
SOLUTION-ANNEAL	AUSTENITE CONDITIONING	MARTENSITIC TRANSFORMATION	AGING	ULTIMATE STRENGTH, psi x 1000		0.2% OFFSET YIELD STRENGTH, psi x 1000		ELONGATION, %	
				17-7 PH	PH 15-7 Mo	17-7 PH	PH 15-7 Mo	17-7 PH	PH 15-7 Mo
A 1950 F±25 F; air cool				130	130	40	55	35	35
REFRIGERATION HARDENING									
	A 1750 1750 F±15 F, 10 min.; air cool	R-100 chill −100 F±10 F; hold 8 hr	RH 950 950 F±10 F, 1 hr; air cool	235	240	220	225	6	6
		ALTERNATE	RMH 950 F±10 F, 2 hr; 900 F±10 F, 3 hr; 850 F±10 F, 3 hr; air cool	250	257	230	235	6	6
LOW-TEMPERATURE HARDENING									
	1180 F±10 F, 2 hr for 17-7 PH, or 1250 F±10 F, for PH 15-7 Mo; air cool	L chill −100 F ±10 F; hold 8 hr	LH 950 950 F±10 F, 1 hr; air cool	235	239	220	222	6	5
		ALTERNATE	LMH 950 F±10 F, 2 hr; 900 F±10 F, 3 hr; 850 F±10 F, 3 hr; air cool	250	255	230	234	6	6
DOUBLE HEAT TREATMENT									
	1400 F±25 F, 90 min.	T from 1400 F, cool to 55 F±5 F within 1 hr; hold 30 min.	TH 1050 1050 F±10 F, 90 min.; air cool	200	210	185	200	9	7
ROLL HARDENING									
		C cold roll 60%	CH 900 900 F±10 F, 1 hr; air cool	265	265	260	260	2	2

I—PH STEELS AT HIGH TEMPERATURES

Temp, °F	17-7PH RH950	17-7PH TH1050	17-7PH CH900	PH 15-7 Mo RH950	PH 15-7 Mo TH1050
			Ultimate Tensile Strength, 1000 psi		
RT	235	200	265	240	210
400	197	174	239	211	195
600	184	162	224	203	182
800	160	143	205	182	165
900	133	124	183	161	144
1000	93	...	...	130	115
			0.2% Offset Yield Strength, 1000 psi		
RT	220	185	260	225	200
400	179	165	223	190	187
600	164	155	204	170	171
800	137	129	176	149	151
900	112	90	145	128	127
1000	76	...	...	101	97
			Elong., %		
RT	6	9	2	6	7
400	5	7	2	4	3
600	7	4	2	5	4
800	12	7	5	8	9
900	16	10	6	11	13
1000	26	...	...	13	21
			100-hr Rupture Stress, 1000 psi		
600	188	170	220	202	179
700	169	130	194	193	161
800	113	110	135	174	139
900	61	78	53	125	108
			1000-hr Rupture Stress, 1000 psi		
600	180	158	216	200	178
700	146	122	180	191	159
800	92	90	73	171	137
900	44	52	36	108	98

II—BEARING & SHEAR PROPERTIES OF PH STEELS

Temp, °F	Direction	17-7 PH RH950	17-7 PH TH1050	PH 15-7 Mo RH950	PH 15-7 Mo TH1050
		Ultimate Bearing Strength, 1000 psi			
Rt	Long	...	...	564	501
	Trans	455	355	487	504
		0.2% Deformation Strength, 1000 psi			
Rt	Long	...	...	405	342
	Trans	392	270	349	342
		Ultimate Shear Strength, 1000 psi			
Rt	Long	149	136	158	144
	Trans	155	136	163	142
200	Long	122	129	152	137
	Trans	148	130	156	136
400	Long	116	123	141	126
	Trans	132	119	137	125
600	Long	114	109	130	117
	Trans	121	110	129	117
700	Long	107	103	126	108
	Trans	119	104	123	111
800	Long	99	94	119	104
	Trans	112	97	116	104
900	Long	87	84	107	94
	Trans	98	86	104	96
1000	Long	65	68	89	81
	Trans	72	70	88	81

III—MEAN COEFFICIENT OF THERMAL EXPANSION

Temp range, °F	17-7 PH RH950	17-7 PH TH1050	17-7 PH CH900	PH 15-7 Mo RH950	PH 15-7 Mo TH1050
		microin./in./°F			
70–200	5.7	5.6	6.1	5.0	6.1
70–400	6.6	6.1	6.2	5.4	6.1
70–600	6.8	6/3	6.4	5.6	6.1
70–800	6.9	6.6	6.6	5.9	6.3
70–1000	...	...	...	6.1	6.6

2. Austenite conditioning. This prehardening heat treatment makes the austenite unstable and favors its transformation to martensite on cooling.

3. Martensitic transformation. These steels harden as they are cooled from conditioning temperatures. They also harden by cold-rolling, without the heat-conditioning steps. Yield strengths range from 90,000 to 190,000.

4. Aging. A final aging step boosts yield and ultimate strengths by 70,000 to 100,000 psi. This is done by a single heating at about 1000 F, or in multiple steps at progressively lower temperatures. The aging simultaneously stress-relieves the part.

Heat treatments

The refrigeration hardening transforms by refrigeration at −100 F (R-100) and final strength is induced by aging at 950 F (RH 950).

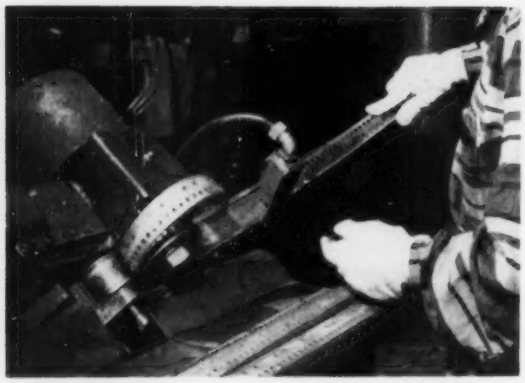
The cooling to room temperature from 1750 F permits clamping the part in shaped dies before completing the quench through the relatively short transformation range from about room temperature to −100 F. These steels then conform accurately to the die shape.

An alternate aging treatment, called multiple hardening, strengthens the material another 10,000 psi without loss of ductility, by aging at successively lower temperatures (RMH). The metal may be cooled to room temperature between each aging treatment or furnace-cooled from one temperature to the next.

The low-temperature hardening sequence conditions at 1180 F for 17-PH (1250 F for PH 15-7 Mo), then follows by refrigeration and aging. Properties from this treatment (condition LH 950) are similar to those of RH 950 but lower conditioning temperatures avoid scaling and cause less distortion. This sequence also has an alternate multiple-hardening treatment (LMH).

The double heat treatment conditions the PH steel at 1400 F, cools and transforms at 55 F, then ages at 1050 F (TH 1050). The hardened material has less strength but is more ductile than by other methods. And those steels with large amounts of cold work do not respond well to this treatment. They must be conditioned at 1550 F and refrigerated to zero F for 4 hr—the material is then aged at the normal 1050 F.

Roll-hardened stock reduced 60% (C) is further strengthened by aging at 900 F (CH 900). Transformation by rolling is more complete and therefore gives higher strength than thermal methods. But ductility is too low



EASY TO FORM, this garbage-disposer shredder ring of 17-7 PH will resist wear and corrosion. Fabrication at Budd Co shows drastic forming the metal can take without process annealing. Clockwise from top left: rolling the pierced blanks; flash welding into a ring; pressing flanges at top and bottom; expanding to size.

for further forming. The cold-worked material is less susceptible to intergranular corrosion than conditioned steels because the rolling does not precipitate carbides at the grain boundaries. It can be descaled by acid; these steels in other hardened conditions cannot.

Properties from different heat treatments

Room-temp tensile strength for each sequence is given at right of the chart. Highest strength is in cold-rolled condition CH 900, but its low ductility (2%) gives poor formability and limits applications to flat sheet or shallow-formed shapes.

Elevated-temp strength (Table 1) also favors the CH 900 treatment. For long-time loads, however, it loses its superiority at 800 or 900 F.

Bearing and shear strengths (Table 2) are better after treatment RH 950 than TH 1050. However, properties from the TH 1050 sequence are more isotropic.

Physical properties such as expansion coefficient vary with the treatment, Table 3. In general, RH 950 gives greater thermal expansion for 17-7 PH than TH 1050. For PH 15-7 Mo, coefficient values are higher with TH 1050. Though these differences are small, they may significantly influence certain critical designs.

How form determines heat treatment

Sheet parts that tend to warp, or parts with close dimensional tolerances, should be clamped in closed dies during transformation. This redistributes the growth to areas where tolerances are not critical or to edges of the sheet that will be trimmed off. Dimensional changes are roughly predictable—growth during transformation is 0.005 in./in. and shrinkage during aging is 0.0005 in./in.

Brazed sandwich panels can be hardened while cooling from the braze cycle with the double heat treat. Because the fixtures holding the part have a relatively large mass, cooling from brazing temperatures (near 1700 F) is slow. The assembly is therefore conditioned by cooling to 1400 F and held for 90 min., then cooled directly to −20 F to ensure complete transformation. Aging is done at 1050 F.

Springs and simple shapes usually start with cold-worked condition C. This form has low ductility—spring coils cannot be wound on mandrels smaller than the wire diameter. Aging to CH 900 both strengthens and stress-relieves. When used for high-temperature springs, these steels are worked less severely to form a more stable structure.

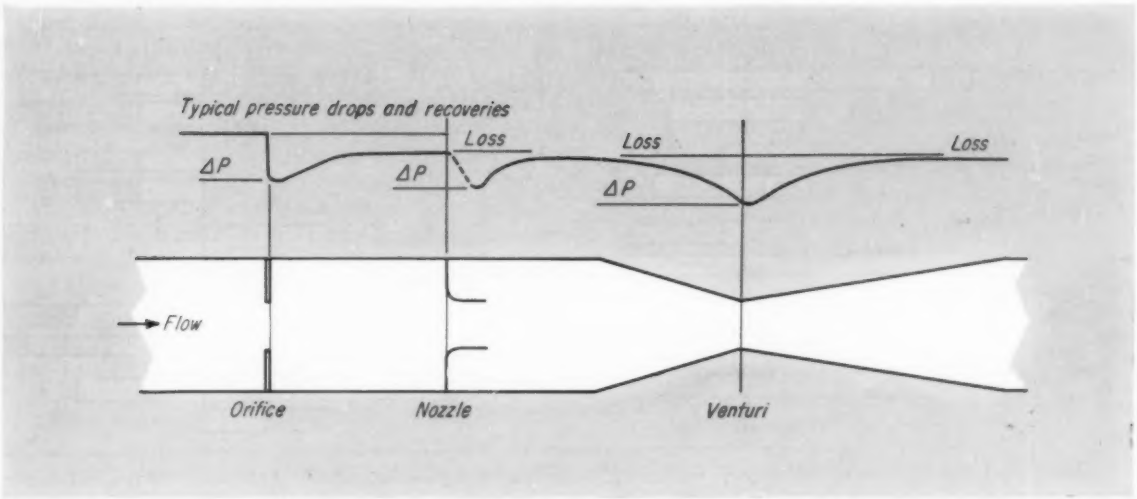
EDITOR'S NOTE: For more on design with hardenable high-strength steels, see:

The High-strength Steels—What They Offer, Jan 23 '61, p 54—Updated data on the newer steels.

Cryogenic Sizing Freezes Accuracy into Hardenable Stainless Steel, Feb 15 '60, p 61—Details on subzero refrigeration process offering close tolerances at low cost for complex parts from the PH semi-austenitic steels.

Also, see our booklet **"Design with Steels."** Comprehensive report gives latest design data on wide range of steels for high strength and high temperatures. It is available from our Reader Service Dept for $2.

—Herbert Kee



HOW TO SELECT A FLOWMETER

This up-to-date roundup not only lists the commercially available flowmeters, plus distinctive special types—it also shows how two steps will simplify the selection procedure

ABOUT THE AUTHORS

As supervisor of the Fluid Mechanics and Combustion Research Section, Armour Research Foundation, since 1956, Dr Miesse has directed research in flow measurement, seal development, cycle analysis, liquid-propellant rockets, jet engines, marine boilers, and automobile afterburners. Previously, he was research engineer at Battelle Memorial Institute and later a physicist for Aerojet-General Corp—where he analyzed unstable burning, atomization and combustion of rocket fuels, and vibration of missile components.

Mr Curth researches problems of fluid flow and controls, and has investigated flowmeters, servo systems, high-temperature high-pressure seals, refrigeration, compressors, valves, 3-dimensional flow sensors, and engines. Before joining Armour, he spent five years under Office of Naval Research sponsorship, investigating vibration and sound-transmission problems for Illinois Institute of Technology.

DR C C MIESSE, *senior scientist*
O E CURTH, *research engineer*
Armour Research Foundation

Here is a familiar situation—you need a flowmeter to measure fluid flow, and it must be designed into the system. One important factor that will determine the choice of meter is—do you want it to measure gas or liquid? The other factors are flow rate, accuracy, temperature range, maximum pressure, and maximum viscosity.

Special considerations also enter the picture: for instance, if you must measure laminar flow in a relatively large area such as a wind tunnel (where you must traverse the area and calculate an average flow) then only a pitot tube will do. Or if you are measuring fuel and need mass-

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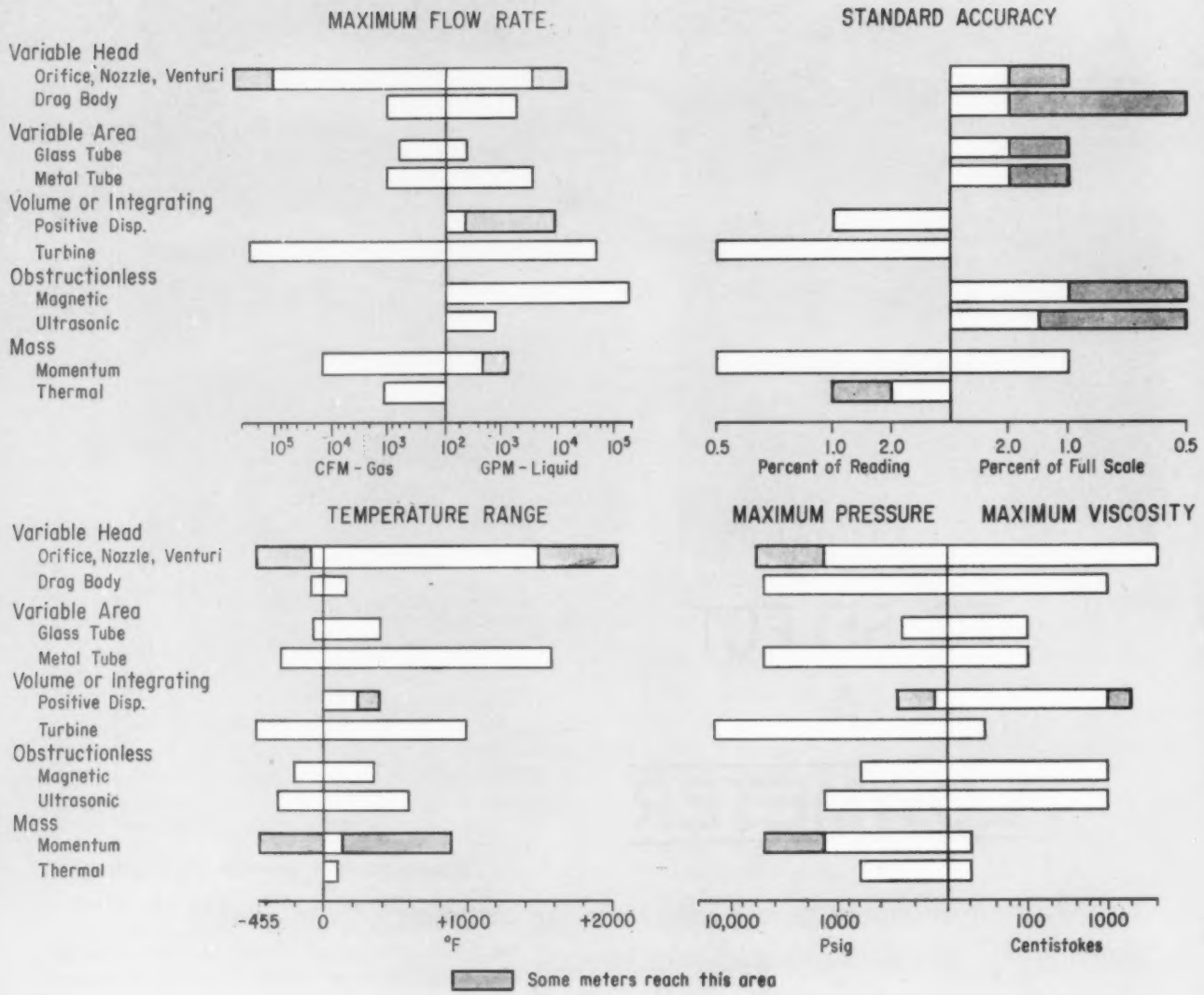

flow or weight-flow information for horsepower or thrust computations, mass flowmeters may be the answer—although many inferential or volume meters can be adapted for mass readings with the right auxiliary equipment.

This article shows how two steps will simplify the selection procedure. If one or more of the other factors are critical, a glance at the bar graphs will quickly eliminate inappropriate flowmeter types. Then take a closer look by turning to the performance table on page 38, where all basic types are compared in detail. Now you are ready to make a final choice, or to query your supplier.

Preliminary selection

When only one of the factors in the bar graph is critical, selection of a flowmeter type is relatively simple. For example, if you need high flow rate for a liquid, the magnetic type stands out, along with the turbine and variable head. Next you turn to the performance table and compare other criteria such as cost and condition of fluid.

If two or more factors are critical, choosing a flowmeter may be more complicated and possibly require some compromise. For instance, suppose you must measure a gas and you need the high flow rate provided by the orifice meter, yet you need the accuracy of the drag body. If the application demands both factors, you may have to turn to the turbine meter as a compromise, but cost will be higher.

The performance table

Flowmeters are listed in the performance table by basic group and by subgroup within each group. Several types that are described later on are not listed in the table—either because they are not commercially available or are beyond the requirements of this article.

Fluid factors. These six columns compare fluids to be measured by quality, quantity, pressure, temperature, and viscosity. Some meters can only handle especially clean fluids and one type, the magnetic, needs a conductive liquid. Most types of meters can measure flow of either gas or liquid, but some are good only for gas (diaphragm, thermal) and some only good for liquid (volume types except diaphragm, and obstructionless types).

Range or maximum flow does not show range of any one meter, but the flow range for each type within which a meter may be procured. The rangeability column gives an indication of how broad each meter's range will be within each type.

Pressure and viscosity are listed by maximum rather than by range because the minimums are unimportant—if you have enough of each to have flow, you can measure it. Temperature is listed in range rather than maximum because of the growing importance of low-temperature measurement.

Application factors. These columns cover the characteristics of the meters themselves—scale, indication, accuracy, materials, and pressure loss. Some types are rate meters, giving instantaneous flow rate. Others are totalizers, giving total quantity of flow, like the water meter in your house. Equipment can be obtained that will adapt a rate meter to a totalizer or vice versa, but this adds to cost. If possible, it's better to decide which function you need, then pick the type that does it naturally.

Almost all flowmeter types provide remote indication (readout), but some such as the rotameter are direct-reading, or local.

Accuracy must be carefully noted because some types are accurate within a certain percentage full scale, and others within a percentage of the reading. Construction materials become important when you're faced with special conditions—high temperatures, corrosive fluids or atmospheres, light weight, etc. Pressure losses are hard to specify exactly by basic type because the flow range and operating pressure of the particular meter have a large influence on this factor. The exception here is the obstructionless types—they handle high rates of flow with no more pressure loss than a straight pipe.

Installation factors. These are factors of line size, special piping, power required, and relative cost. For purposes of this article, only minimum line sizes are significant. For other applications, some types listed will handle 2-, 3- or even 6-foot pipelines.

Special piping is required for the variable-head meters because they measure differential pressure which must be picked off at certain distances upstream and downstream from the restriction. Other types must be installed in certain positions—for example, the rotameters must be vertical in order to operate.

Some of the more complex and expensive types require external power to operate. Mass flowmeters even need a special motor to drive them at a known constant speed.

Cost is listed on a relative basis only, because it will vary by manufacturer, flow range, accuracy, extra equipment, and so on, depending on your particular requirements within a basic type.

HOW TO SELECT A FLOWMETER

STANDARD FLOWMETER TYPES

Variable-head meters

Variable-head meters measure pressure differential across a restriction placed in a pipeline. Volume flow for liquid is calculated using the equation:

$$Q = CA\sqrt{2gh}$$

where Q is flow, cu in. per sec; C is discharge coefficient; A is orifice area, sq in.; g is acceleration of gravity, in. per sec^2; and h is pressure drop across the restriction, in inches of column height. For gas, a more complex equation is needed, but often the liquid equation is used with suitable correction factor.

Head meters consist of a primary element, which is a restriction containing an aperture, and a secondary element, such as a manometer, bell gage, or bellows or diaphragm. Primary elements can be an orifice plate, nozzle, venturi, drag body, capillary tube, or pitot tube. Because these meters have long been the most popular and versatile type, much empirical data has been published on discharge coefficients, and sizes and combinations of primary and secondary elements. Head meters are available in a wide range of flow quantities, line sizes, and materials.

When used with other equipment, such as a densitometer which compensates for density changes, head meters can measure mass flow. The equation becomes:

$$W = CA\sqrt{2\rho\Delta p}$$

where W is flow rate, lb; C is discharge coefficient (not necessarily same as C used for volume flow); A is cross-sectional area, sq in.; ρ is density; and Δp is pressure drop across the restriction, ft.

ADVANTAGES. Accuracy, economy, availability. Also, versatility. You can buy any of the primary devices and supply your own secondary, or you can buy a combination of the two. Adaptable to remote indicating and recording.

DISADVANTAGES. Pulsing flow, as well as changes in density, temperature, pressure and viscosity, affect accuracy. Because relationship between differential pressure and flow is nonlinear, flows less than 20% of the instrument's maximum capacity are impractical to measure. Rangeability is about 3:1.

Pressure recovery is never 100% (pressure downstream of the restriction never recovers from the pressure drop caused by the restriction). Illustrations on p 35 show effect of three primary head meter elements on recovery.

text continued, page 39

PERFORMANCE CHARACTERISTICS OF FLOWMETERS BY

METER TYPE		FLUID FACTORS						APPLICATION FACTORS				
		Fluid	Range of Max Flow: Liquid, gpm Gas, cfm	Useful Range-ability	Max Pressure, psig	Temp. Range, °F	Max Viscosity, centistokes	Scale	Indication	Standard Accuracy	Construction Materials	Pressure Loss, psi
VARIABLE HEAD	Orifice	Liquid Gas	0.2–3500 50–100,000	5:1	6000	−455 to 2000	4000	Sq rt. Rate	Remote diff. press.	1–2% full scale diff. press.	Most metals	0.1–30
	Flow Nozzle	Liquid Gas	0.5–15,000 100–500,000	5:1	1500	−60 to 1500	4000	Sq rt. Rate	Remote diff. press.	1–2% full scale diff. press.	Bronze, iron, steel, stainless stl.	0.1–20
	Venturi	Liquid Gas	0.5–15,000 100–500,000	5:1	1500	−60 to 1500	4000	Sq rt. Rate	Remote diff. press.	1–2% full scale diff. press.	Bronze, iron, steel, stn. stl., plastic	0.1–15
	Drag Body (Var. Force)	Liquid Gas	0.5–2000 5–1000	5:1	5000	−60 to 180	1000	Sq rt. Rate	Remote electric	½–2% full scale	Steel, stn. stl.	2–50
VARIABLE AREA	Glass Tube Rotameter	Liquid Gas	5cc/min–250 400cc/min 700	10:1	250	−50 to 400	100	Linear Rate	Local or remote electric or pneumatic	1–2% full scale	Most metals, plastics & ceramics	0.2" H_2O to 1.0 psi
	Metal Tube Rotameter	Liquid Gas	0.5–4000 0.6–1000	10:1	5000	−300 to 1600	100	Linear Rate	Local or remote electric or pneumatic	1–2% full scale	Most metals, plastics & ceramics	1.0" H_2O to 10 psi
VOLUME OR INTEGRATING	Reciprocating Piston	Clean liquids	0.002–200,000	10:1 to 20:1	250	0 to 250	1000	Linear Total	Local or remote electric	1% reading	Bronze, iron steel, stn. stl.	1–20
	Rotary Piston	Clean liquids	5–8750	10:1 to 20:1	3000	0 to 300	2000	Linear Total	Local or remote electric	1% reading	Bronze, iron, steel, stn. stl.	1–20
	Nutating Disk	Clean liquids	0.25–1000	10:1	150	0 to 300	2000	Linear Total	Local or remote electric	1% reading	Bronze, iron, steel, stn. stl.	1–20
	Diaphragm	Gas	0.25–500	20:1	100	−30 to 180	all gas	Linear Total	Local	1% reading	Steel, aluminum, syn rubber	1" H_2O to 1.5 psi
	Turbine or Propeller	Clean liquid or gas	0.004–50,000 0.5–300,000	15:1 10:1	15,000	−455 to 1000	30	Linear Total	Remote electric	½% reading	Aluminum, stn. stl.	2–10
OBSTRUCTIONLESS	Magnetic	Conductive liquids only	0.002–50,000	20:1	600	−200 to 360	1000	Linear Rate	Remote electric	½–1% full scale	Plastic, stn. stl. with non-conductive liner	same as line
	Sonic or Ultrasonic	Liquid	0.1–800	20:1	1500	−300 to 600	1000	Linear Rate	Remote electric	1–1½% full scale	Bronze, steel, stn. stl.	same as line
MASS	Momentum Gyroscopic	Liquid Gas	100–4000 ppm 20–600 ppm	10:1	1500	0 to 165	20	Linear Total Rate	Local or remote electric	1% full scale	Bronze, steel, stn. stl.	1–10
	Momentum Axial	Liquid Gas	40–100,000 ppm 10–15,000 ppm	10:1	5000	−430 to 850	20	Linear Total Rate	Remote electric	½% reading	Aluminum, stn. stl.	5–20
	Thermal	Gas	1.0 gm/min to 80 ppm	20:1	600	0 to 100	all gas	Logarithmic Rate	Remote electric	1–2% reading	Bronze, steel, stn. stl	low

BASIC GROUPS

INSTALLATION FACTORS			
Line Size, in.	**Special Piping Considerations**	**Typical Power Requirement**	**Relative Cost**
1½–12 & larger	Straight pipe: 10 diameters upstream; 3 downstream	None	1.0
1–24 & larger	Straight pipe: 10 diameters upstream; 3 downstream	None	1.4
1–24 & larger	Straight pipe: 10 diameters upstream; 3 downstream	None	1.5
½–12	Vertical or horizontal	115 v 60 cps 20 w	1.0–4.0
¼–4	Vertical only	None	1.0
½–12	Vertical only	None	1.2
¾–3	Horizontal recommended	None	1.0–2.0
⅝–16	Horizontal recommended	None	1.0–2.0
½–6	Horizontal recommended	None	1.0
¼–4	Horizontal recommended	None	1.0
⅛–36	Any position	115 v 60 cps 50 w	5.0
1/10–78	Any position	115 v 60 cps 200 w	6.0
¼–2	Any position	115 v 60 cps 100 w	10.0
1–3	Horizontal recommended	115 v 60 cps 50 w	4.0–5.0
1–12	Horizontal recommended	115 v 60 cps 50 w	6.0–8.0
⅛–6	Any position	115 v 60 cps 10 w	1.0–4.0

HOW TO SELECT A FLOWMETER

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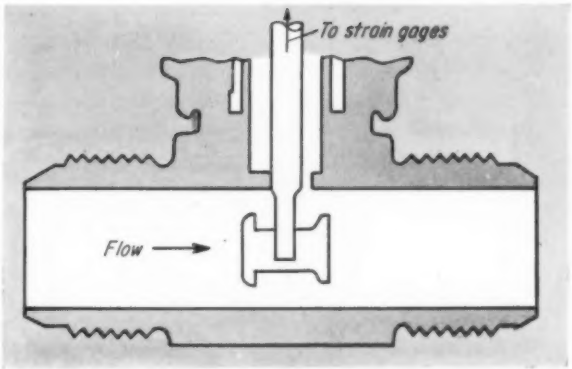
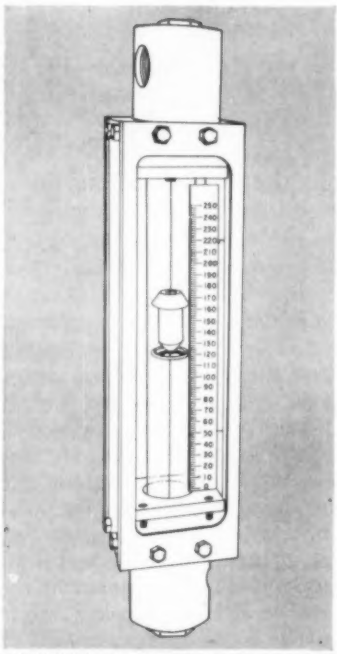


DRAG BODY, Ramapo Instrument Co



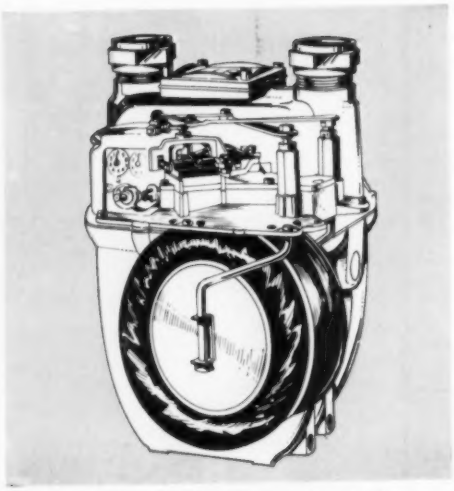
ROTAMETER, Brooks Rotameter Co

Orifice type consists of a thin plate containing a sharp-edged orifice, usually installed between pipe flanges in a line. Orifice diameter is ordinarily fixed at some proportion to line diameter, from 0.2 to 0.8. Instruments with smaller or larger diameters (0.1 or 0.9) require individual calibration. Exact orifice diameter can be calculated from application conditions of line size, flow quantity and condition, and differential pressure. Flow coefficients have been empirically established for all practical conditions, and are available in flow-calculation manuals or from your supplier.

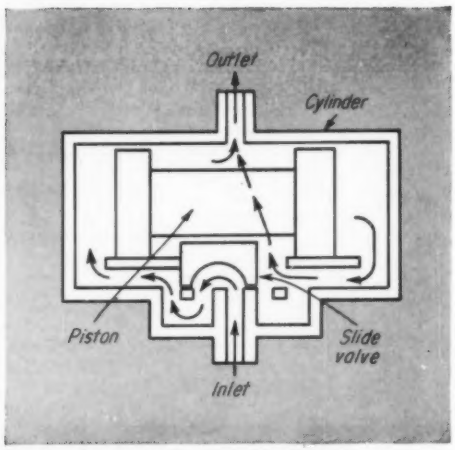
A method for obtaining mass flow rate by recirculating the flow through two identical orifices will be covered in a forthcoming article now in preparation.

Pressure taps for secondary elements must be located

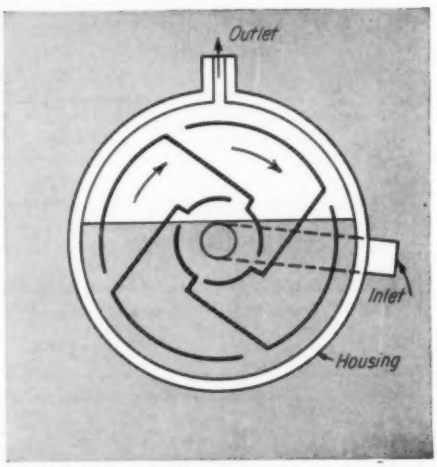
HOW
TO SELECT
A
FLOWMETER



DIAPHRAGM GAS METER, Rockwell Mfg Co



RECIPROCATING-PISTON METER



REVOLVING-DRUM METER

where turbulence is at a minimum. Flange taps, the most commonly used connection, are located 1 in. upstream and 1 in. downstream of the orifice. Because they are symmetrical, they can measure flow in either direction, providing you turn the orifice around. Also, because they are located close to the flange, they are accessible for inspection, and are located by the manufacturer of the flange, thus eliminating possible location errors. Two other arrangements for locating taps are sometimes used: the vena contracta taps, located upstream about 1 pipe diameter and downstream at the point of minimum static pressure, which are a little more accurate than flange taps because they sense maximum pressure differential; and pipe taps, located 2½ pipe diameters upstream and 8 diameters downstream, which measure permanent pressure losses.

ADVANTAGES. Simple to install, economical, data available, accurate, wide range of materials.

DISADVANTAGES. Requires straight run of pipe, has lower pressure recovery; is inaccurate for high viscosities (below Reynolds number of 15,000), and low static-pressure applications such as blowers; handles clear fluids only (except for special segmental and eccentric types). The Reynolds number is a dimensionless index of ratio of inertia to viscosity. When number is high, inertia forces predominate and viscosity forces are insignificant; when Reynolds number is low, viscosity effects are important, causing the discharge coefficient to become a variable, seriously complicating measurement.

Flow nozzle consists of a flared inlet section followed by a cylindrical throat, whose diameter is generally between 0.25 and 0.7 of line diameter. Not as convenient or cheap as an orifice plate, the flow nozzle is often used for higher flow rates, or higher viscosities.

ADVANTAGES: Easy to install between flanges; handles dirty fluids compared with orifice type, it is more accurate for high velocity flow, gives better pressure recovery, and is less susceptible to inaccuracies due to wear.

DISADVANTAGES: Expensive to make; hard to remove from line, cannot ordinarily be modified to handle higher capacities.

Venturi is similar to flow nozzle except that the throat section is short and gradually diverges to pipeline diameter. This taper effect yields best pressure recovery of differential-pressure types. When cost permits, venturis are used where accurate flow measurement must be made with minimum loss of energy.

ADVANTAGES: Most accurate of pressure-differential types; excellent pressure recovery; good for large volumes of dirty fluids.

DISADVANTAGES. Expensive, hard to make, awkward to install, hard to modify for changes in flow range.

Pitot tube contains two pressure passages. One faces into flow, sensing total pressure; the second faces perpendicular to flow, sensing only static pressure. The difference in pressure between the two is a measure of velocity. But, because it senses velocity at only one point, the pitot tube must traverse a cross-section of the flow area measuring differential at various points. The velocities are then averaged and flow is determined by the equation: $Q = Av$, where A is cross-sectional area of line, v is average velocity.

ADVANTAGES: Very little energy consumption; simple to instal; single element can be used for most line sizes; inexpensive.

DISADVANTAGES: Relatively inaccurate; handles clean fluids only; takes time and patience to traverse.

Drag body senses the velocity of fluid flow as a function of the dynamic forces acting upon a fixed body in the flow stream. One type contains bonded strain gages in a bridge circuit, completely isolated from the fluid by a wall of stainless steel. Force on drag body deflects a rod carrying the gages. Electrical output is proportional to the square of the original flow rate.

ADVANTAGES. Can be most accurate of differential pressure meters; can operate in either direction.

DISADVANTAGES. Requires external power and meter; sensitive to shock, vibration.

Capillary type is used for very low flow ranges, and for higher viscosities—where the Reynolds number is below 15,000. Device operates on the principle that the quantity of fluid passing through a small tube in a given time is proportional to the pressure difference causing the flow times tube diameter to the fourth power over the reciprocal of tube length times viscosity. For this so-called Hagen-Poisenille law, the equation is:

$$Q = \frac{\pi \Delta p d^4}{128 \mu l}$$

where Δp is pressure drop, d is tube diameter, μ is viscosity, l is length.

Variable-area meters

These meters also operate by means of differential pressure, but whereas head meters contain a fixed aperture and measure differential pressure, area meters maintain a relatively constant differential pressure and measure the aperture area as it varies with flow. The most common device of this type is a rotameter, which consists of a vertical tapered glass tube containing a tapered weight. The amount of cross-sectional area is determined by height of the weight as it is suspended by the force of pressure. Differential pressure remains constant because the weight is constant—as flow is increased, the weight is forced higher in the tube, causing the area to increase. The tube is graduated so that flow rate can be read directly. Another variable-area meter is the metal tube or cylinder-and-piston type: a piston is accurately fitted inside a cylinder and is lifted by fluid pressure until enough port area in the cylinder is opened to permit passage of the flow.

ADVANTAGES. Secondary elements not needed; accurate over wide range, including low flow; handles corrosive fluids; direct reading, or can be used with magnetic following devices for remote reading; small capacity changes can be accomplished by simple changes in weight; no special upstream or downstream piping needed; pressure loss is small, constant.

DISADVANTAGES. Glass tube must be cleaned; dirty fluid requires remote readout, defeating meter's basic simplicity; though "relatively constant," differential pressure increases as flow increases because of frictional forces within meter; requires damping devices for pulsing flow.

Positive-displacement meters

Displacement meters are totalizers. They chop the flow into known volumes and count the number of chunks. Except for the diaphragm type, they share the following:

ADVANTAGES. Simply designed; accurate, even for low end of flow range; available in different materials and calibrations for measuring widely different fluids.

DISADVANTAGES. Maintenance is high because of moving parts; wear destroys accuracy; requires vapor trap upstream if entrained gas is present in liquid; relatively expensive to obtain instantaneous flow rates.

Diaphragm type is a gas flowmeter. It consists of a divided housing, two diaphragms, two sliding valves, a crank, a tangent arm, and linkage. When gas flows, the valves cause one diaphragm to fill and the other to empty, each acting as a reciprocating piston. Through linkage from the diaphragms, the crank's tangent arm picks up the reciprocating motion and turns the crank. Rotation of the crank is directly proportional to motion of the diaphragms, which in turn is proportional to the volume of gas flowing.

ADVANTAGES. Economy; linear; measures volume directly.

DISADVANTAGES. Gas only; relatively low pressure.

Reciprocating piston type is available in many variations. One common type uses two cylinders, a double-ended piston, and a sliding valve. When valve is in left position, fluid enters and is directed against piston on left, pushing entire piston assembly to right, and forcing out fluid trapped by right piston. When assembly reaches extreme right position, sliding valve moves to right. Fluid is then directed against right piston and assembly is pushed to left, forcing out fluid trapped on left side. Pistons are connected to crank arm which positions sliding valve and operates counting mechanism.

Revolving drum measures flow of gases. The measuring element is a drum partly submerged in a liquid. The gas bubbles through the liquid, pushing against partitions in drum, causing drum to rotate and release gas at the outlet.

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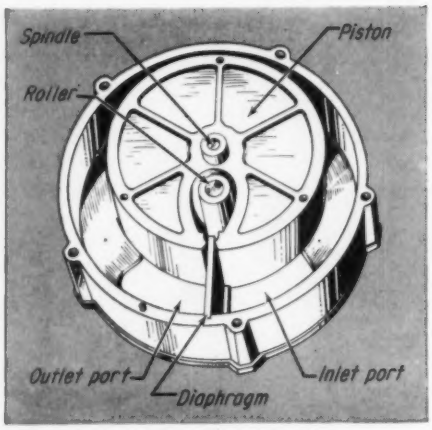
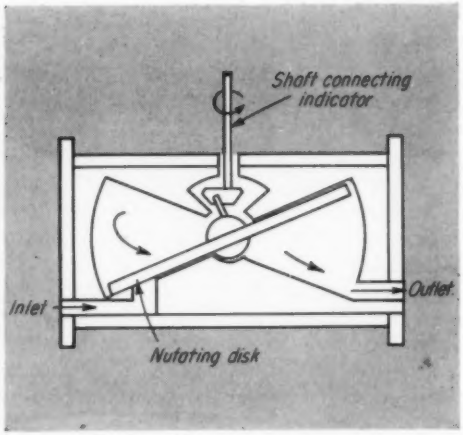
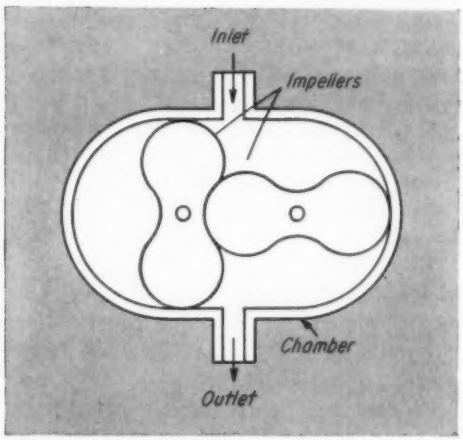
HOW TO SELECT A FLOWMETER



ROTATING-PISTON METER,
Neptune Meter Co



NUTATING-DISK METER



LOBED-IMPELLER METER

Rotating piston, or vane type, consists of a piston mounted eccentrically inside a cylinder. The piston contains spring-loaded sliding vanes which continually maintain contact with the cylinder wall. Fluid entering the cylinder is trapped by the vanes and causes the piston to rotate until it is carried around to the outlet port; here it is forced out by the decreasing volume of space between vanes.

Nutating disk measures liquid. The disk rocks or nutates when liquid enters the inlet. Each nutation cycle discharges a discrete volume of liquid through the outlet. Simple design, relatively low cost, and minimum maintenance make this type most commonly used displacement meter.

Lobed-impeller meter measures gas flow, and operates much like the rotating piston. Two rotors revolve in a fixed position inside the chamber. They are shaped to maintain contact between the housing and each other. As the gas enters the chamber, it is trapped by the rotors and carried around to the outlet. Flow is totalized by counting revolutions.

True-mass flowmeters

Mass flowmeters are also called transverse-momentum meters because they impart a known, constant velocity to the fluid at right angles to its direction of flow. The force required to accelerate or retard the fluid stream is equal to the rate of change of momentum in the transverse direction, which in turn is proportioned to the mass rate of flow.

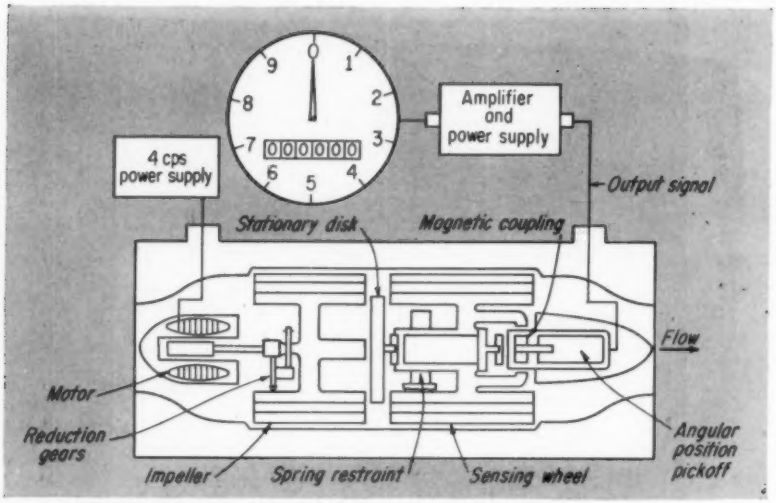
ADVANTAGES. Mass flow is indicated directly, unaffected by changes in density, temperature, pressure, viscosity, compressibility; indicates rate and total flow.

DISADVANTAGES. Expensive; require rotating seals; require highly accurate, constant-speed drive.

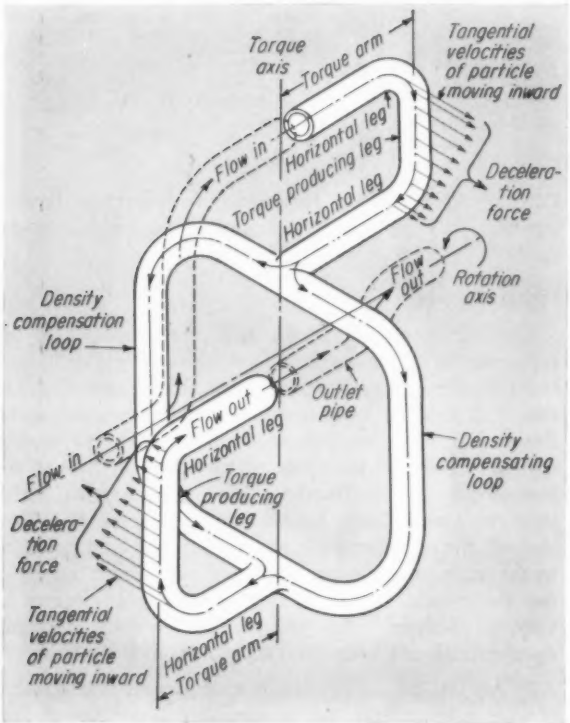
Axial flowmeter contains an impeller and a torque-sensing wheel. The impeller is driven at a constant angular velocity. The torque wheel senses the total angular momentum, and subtracts the known momentum added by the impeller. The remaining momentum produces a torque proportional to mass rate of flow. The torque-sensing wheel is spring-restrained and magnetically coupled to an angular position pick-off.

A second version of the axial flowmeter contains two impellers, driven in opposite directions, with the torque-sensing wheel between them. The sensing wheel is restrained electromechanically instead of mechanically with a spring. Flow can be measured in either direction with this method, but pressure drop is greater because of the second impeller.

Gyroscopic type uses tubing bent in the form of a circle or square. The device is spun about the x axis while fluid is flowing through the tubing. As with a gyro, a moment acting about an axis perpendicular to both x and y is produced. The moment is a function of both angular rotation and mass flow-rate.



AXIAL MASS FLOWMETER, General Electric Co



GYRO MASS FLOWMETER, Norwood Controls Div, Control Engineering Corp

A refinement of the gyroscopic meter is the vibrating gyro. Here, flow rate is indicated by the amplitude of resultant vibration. Advantages are: no flow obstruction, mass flow-rate is indicated directly, design is simple, and pressure drop is low. Disadvantages include excessive vertical-space requirements, sensitivity to turbulence, and nonlinearity at low flow rates.

Magnetic flowmeter

Based on Faraday's law of electromagnetic induction, a magnetic flowmeter consists of a piece of straight pipe, an electric coil set to produce a magnetic field perpendicular to flow, and a set of electrodes located at right angles to both magnetic field and flow. When liquid flows, the voltage induced is proportional to average velocity of liquid, strength of magnetic field, and distance between electrodes. In a given meter, the magnetic field and distance between electrodes are constant, therefore the induced voltage is directly proportional to flow velocity.

ADVANTAGES. High sensitivity and accuracy; wide flow range can be measured in either direction; output is linear; pressure loss is negligible—same as for straight pipe; handles many materials, clean or dirty; temperature and viscosity changes have little effect on accuracy.

DISADVANTAGES. Expensive; liquids must be conductive; maximum ambient temp is about 135 F, fluid to 400 F.

Sonic velocity flowmeter

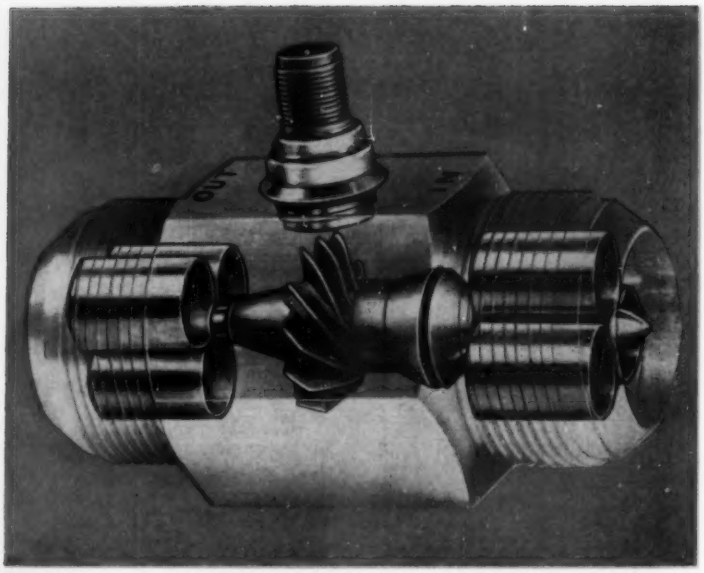
Similar to magnetic flowmeter in that there is no obstruction to flow, the sonic velocity flowmeter consists of two ultrasonic transmitters and two receivers located so that one pair operates against the direction of flow (or upstream) and the other pair with flow (downstream). If both transmitters send on the same frequency, the difference in phase at the receivers between the two pairs is proportional to fluid velocity.

ADVANTAGES. Because of straight pipe, pressure loss is negligible; volumetric measurement unaffected by density change; readout can easily be analog or digital; can operate in any position.

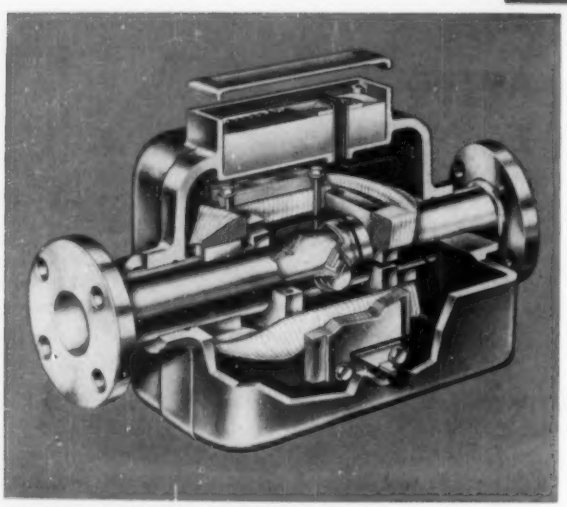
continued, next page

HOW
TO SELECT
A

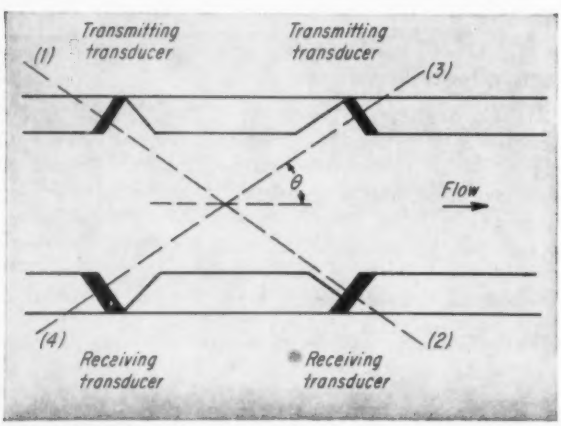
FLOWMETER



TURBINE (Pottermeter), Potter Aeronautical Corp



MAGNETIC METER, Fischer & Porter Co



SONIC METER

DISADVANTAGES. Expensive; temperatures limited between −65 and 165 F; high viscosities cannot be measured.

Thermal meters

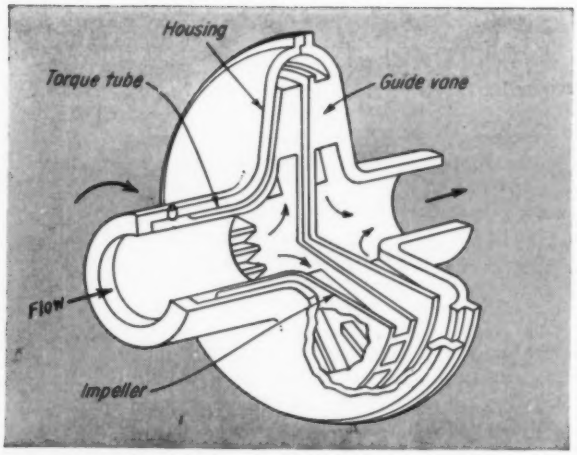
Used for measuring gas, thermal meters operate on the principle that when supplied from an outside source, heat is absorbed in a flowing stream proportional to the rate of flow. A thermal flow chamber contains a noble-metal thermopile. The hot junctions are heated by alternating current. The cold junctions, which sense the heat in the flow stream, are constructed to discourage heating: resistance is lower, heat conductivity is increased. Flow through the chamber tends to bring hot and cold junctions to the same temperature, which reduces voltage output of the thermopile. Thus voltage output is a measure of velocity of flow. As flow increases, voltage decreases asymptotically to zero, producing a logarithmic scale.

ADVANTAGES. Logarithmic scale permits measurement of wide range of flow; low pressure loss; fast response; flow element is relatively low cost.

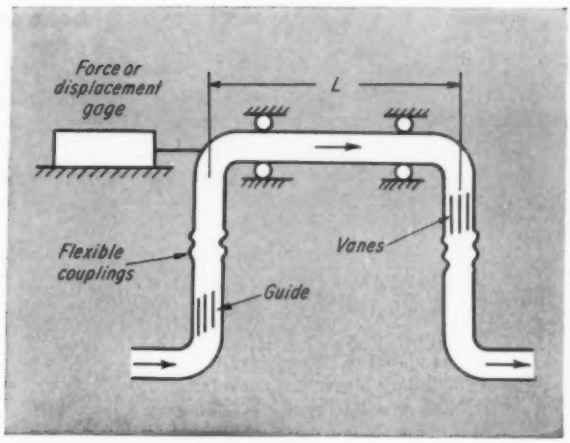
DISADVANTAGES. Gas only; element must be protected from foreign particles by fine-mesh screen.

Turbine flowmeters

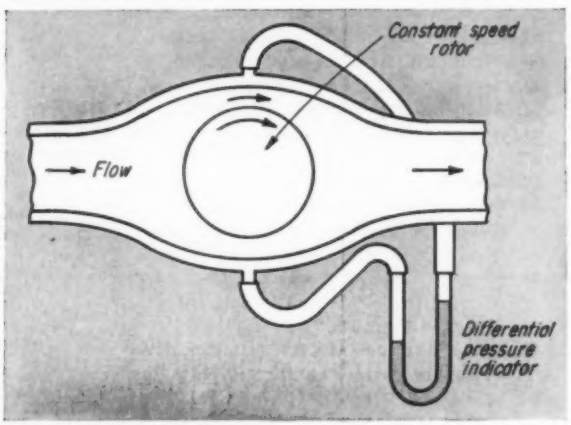
Turbine meter contains a turbine wheel which rotates at a speed proportional to fluid velocity. Inside the wheel is a small permanent magnet, polarized at right angles to axis of rotation. As the wheel turns, pulses are generated in a coil mounted outside the housing. (A second type uses the turbine blade tips to induce the electrical pulses.)



RADIAL FLOWMETER



FLOW-ACCELERATION METER



MAGNUS-EFFECT METER

Frequency of the pulsating signal gives the instantaneous flow rate, and the number of pulses totalizes the flow.

ADVANTAGES. Handles high pressures; high accuracy; quick response.

DISADVANTAGES. Abrasive media shorten bearing life; severe pulsing flow and shocks affect calibration, which must be verified.

SPECIAL-INTEREST TYPES

Radial flowmeter

The radial (Coriolis) type is a mass flowmeter, similar to a centrifugal pump. Fluid entering at the hub is deflected from its axial path by a vaned impeller. As the fluid moves away from the impeller's center of rotation, its tangential velocity increases—reflecting the effect called Coriolis acceleration. With the impeller rotating at constant rpm, the acceleration is also constant, and the force required to tangentially accelerate fluid flow is proportional to mass flow-rate.

ADVANTAGES. Handles gases, liquids, foams, slurries; produces pressure rise rather than pressure drop; fast, linear response; adaptable to standard recording, indicating and controlling equipment.

DISADVANTAGES. Requires highly accurate, constant-speed drive; needs much maintenance; requires rotating seals.

Magnus-effect flowmeter

The fluid passes in two streams around a rotating cylinder as shown in the sketch. Flow in upper stream tends to be greater because the cylinder surface moves in same direction as the flow. The lower flow tends to be retarded. Net effect is to increase static pressure in the lower path, and decrease it in the upper. Pressure differential will be directly proportonal to mass flow if these assumptions are valid: flow in each passage is potential-type only (based on flowline concepts); effective "circulating" flow velocity (caused by constant cylinder rotation) is constant for any fluid; total flow is the same whether cylinder is stationary or rotating. The assumptions are not usually valid, however, and careful calibration is needed.

Flow-acceleration meter

Mass rate of flow is obtained by integrating the force required to accelerate the fluid in a given length of conduit. Flexible couplings isolate the conduit so that any horizontal force acting on it can be determined by measuring its horizontal displacement. The fluid must be assumed to be incompressible and homogeneous. Accuracy is limited only by accuracy of the integrator.

continued, next page

Acknowledgments

Many suppliers of components assisted in the preparation of this article. Our special thanks go to Charles E. Smith, projects manager, Minneapolis-Honeywell Regulator Co, Missile Equipment Div, Pottstown, Penna, for his assistance in preparing the tables, and to J. J. Combes, instrumentation engineer, Process Plants Div, Foster Wheeler Corp, New York 17, who served as our consultant. We wish also to thank the following companies for their technical assistance:

1. Avien Inc, Woodside, NY
2. Bailey Meter Co, Cleveland 10
3. Bennet-Ferrzgen Co, Monterey Park, Calif
4. Bowser Inc, Fort Wayne, Ind
5. Ralph N Brodie Co, San Leandro, Calif
6. Brooks Rotameter Co, Lansdale, Penna
7. Brown Instrument Div, Minneapolis-Honeywell Regulator Co, Long Island City, NY
8. Buffalo Meter Co, Buffalo 14
9. B I F Industries Inc, Providence, RI
10. Central Station Steam Co, Detroit 7
11. Cox Instruments Div, Geo L Nankervis Co, Detroit 17
12. Decker Corp, Bala Cynwyd, Penna
13. F W Dwyer Mfg Co, Michigan City, Ind
14. Eclipse Fuel Engineering, Rockford, Ill
15. R A Eckstrom Co, Eddystone Div, Baldwin-Lima-Hamilton, Philadelphia 42
16. Fluid Dynamics Inc, Monrovia, Calif
17. Fischer & Porter Co, Warminster, Penna
18. Flow Measurements Corp, Kensington, Md
19. Foster Engineering Co, Union, NJ
20. The Foxboro Co, Foxboro, Mass
21. General Electric Co, West Lynn, Mass
22. Gulton Industries Inc, Vibro-Ceramics Div, Metuchen, NJ
23. Hagan Corp, Pittsburgh 30
24. Hastings-Raydist Inc, Hampton, Va
25. Hersey-Sparling Meter Co, Dedham, Mass
26. The W L Maxson Corp, New York 18
27. The Meriam Instrument Co, Cleveland
28. Neptune Meter Co, New York City
29. New Jersey Meter Co, Plainfield, NJ
30. Nuclear Corp of America, New York City
31. Penn Instrument Div, Burgess Manning Corp, Philadelphia 4
32. Pioneer-Central Div, Bendix Corp, Davenport, Iowa
33. Potter Aeronautical Corp, Union, NJ
34. Precision Scientific, Chicago
35. Ramapo Instrument Co, Bloomingdale, NJ
36. Rotron Controls Corp, Woodstock, NY
37. Quantum Dynamics, Tarzana, Calif
38. Republic Flow Meters Co, Chicago 47
39. Revere Corp of America, Wallingford, Conn
40. Rockwell Mfg Co, Pittsburgh 8
41. Roots-Connersville Blower Co, Connersville, Ind
42. Schutte & Koerting Co, Bucks County, Penna
43. Selas Corp, Dresher, Penna
44. Sentry Equipment Corp, Oconomowoc, Wis
45. Simmonds Precision Instrument Co, Tarrytown, NY
46. Simplex Valve & Meter Co, Lancaster, Penna
47. A O Smith Co, Meter Div, Milwaukee
48. Standard Controls, Seattle 44
49. Taylor Instrument Co, Rochester, NY
50. Trans-Sonics Inc, Lexington, Mass
51. Wallace & Tiernan, Newark, NJ
52. Waugh Engineering Co, Van Nuys, Calif

A Shopping Guide—by Basic Type

Once you decide on a basic type of flowmeter, the list below will direct you to some of the suppliers of each type. The numbers refer to the manufacturers who are listed, in alphabetical order, under "Acknowledgments."

ORIFICE	2, 7, 17, 20, 23, 27, 38, 45, 49
NOZZLE	2, 7, 9, 17, 19, 20, 23, 27, 31, 38, 46, 49
VENTURI	2, 7, 9, 17, 20, 23, 27, 31, 38, 46, 49
DRAG BODY	14, 29, 35, 48
GLASS TUBE	3, 6, 11, 13, 15, 17, 29, 42, 43, 44, 51
METAL TUBE	6, 7, 11, 17, 29, 42, 51
RECIP. PISTON	4, 5, 47
ROTARY PISTON	5, 10, 28, 34, 40, 41, 47
NUTATING DISK	8, 28, 40
DIAPHRAGM	40, 41
TURBINE	11, 17, 25, 33, 35, 36, 39, 52
MAGNETIC	4, 17, 20, 30, 49
SONIC	18, 22, 26
GYROSCOPIC MOMENTUM	7, 12, 16, 21
AXIAL MOMENTUM	1, 18, 32, 33, 37
THERMAL	18, 24, 50

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EDITOR'S NOTE: For information on the use of fluids in hydraulic and pneumatic systems, see:

Evaluating Fluid-filtering Media, Nov 28 '60, p 29—Author presents basic information for understanding how to choose filters for hydraulic and pneumatic systems. Included are tables comparing performance of typical filter media constructions and compatibility of fluids and filters.

Modern Fluids for Power and Control, Jan 18 '60, p 56—Covers all conventional fluids, including fire-resistant types; gives important physical properties and chemical compatibility with seals and packings.

Pressure Losses in Pneumatic Systems, Oct 26 '59, p 50—Simple calculations for pressure drops of components in series. Nomograph method extends NBS techniques.

Pressure Losses in Hydraulic Branch-off Fittings, July 20 '59, p 60—Performance curves for flush, elbow, and probe-type takeoffs relate losses to branch-to-main velocity ratio, branch-off angle and design.

A future article covers laminar meters (capillary, porous plug) and special adaptations of variable-head meters.

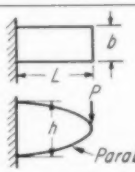
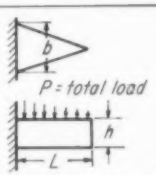
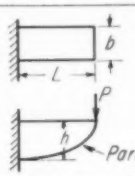
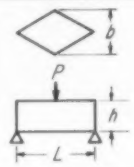
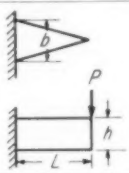
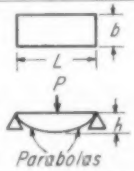
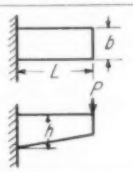
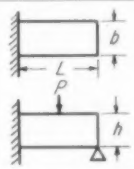
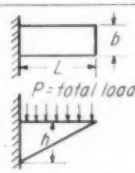
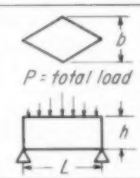
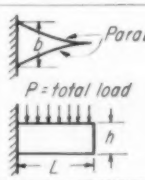
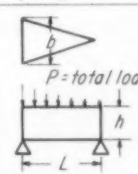
—Frank Hall

SINGLE NOMOGRAPH FOR

18 CONSTANT-STRENGTH BEAMS

With help of K factor it finds total load the beam will carry, and maximum bending moment.

WILLIAM GRIFFEL
Ordnance engineer
Picatinny Arsenal

Type	K		Type	K	
1	1		7	3	
2	1		8	4	
3	1		9	4	
4	1		10	5.3	
5	2		11	6	
6	2		12	7.8	

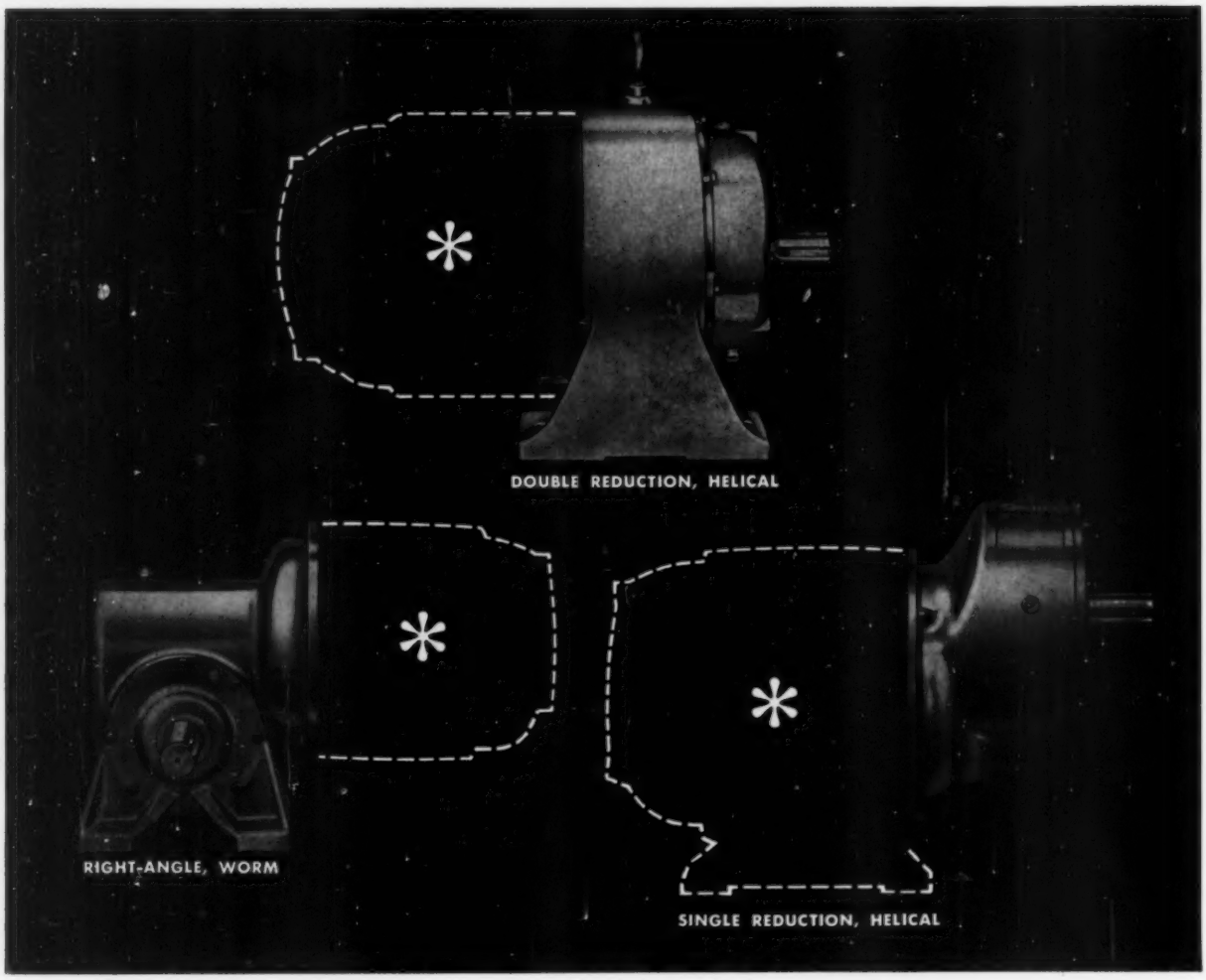
A constant-strength beam has the same maximum bending stress at every section; consequently, there must be just enough material at every cross-section—and no more. Since stress $S = Mc/I$, this is done by varying the shape so that I/c changes with M. Each shape keeps stress constant for only one specific combination of support and loading conditions. Because the shape takes only bending stresses into account, material may have to be added at the supports and at the load to withstand shear.

Several different beams are shown in the sketches at right. For each there is listed a value of $K = PL/M$. Given K, beam dimensions and safe stress, the nomograph will solve for total load $P = SKbh^2/6\,L$, and maximum bending moment.

EXAMPLE: What is the carrying capacity (lb/in. of length) of a type-6 constant-strength beam if $b = 1.9$ in., $h = 2.0$ in., $L = 30$ in. and $S = 70{,}000$ psi?

Solution: From the chart $K = 2$. The nomograph gives total load $P = 6000$ lb. Carrying capacity $= P/L = 6000/30 = 200$ lb/in.

continued, page 49



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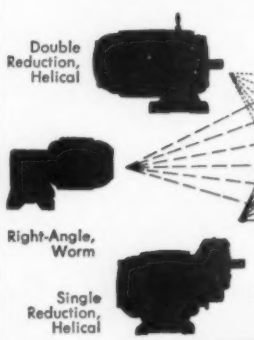

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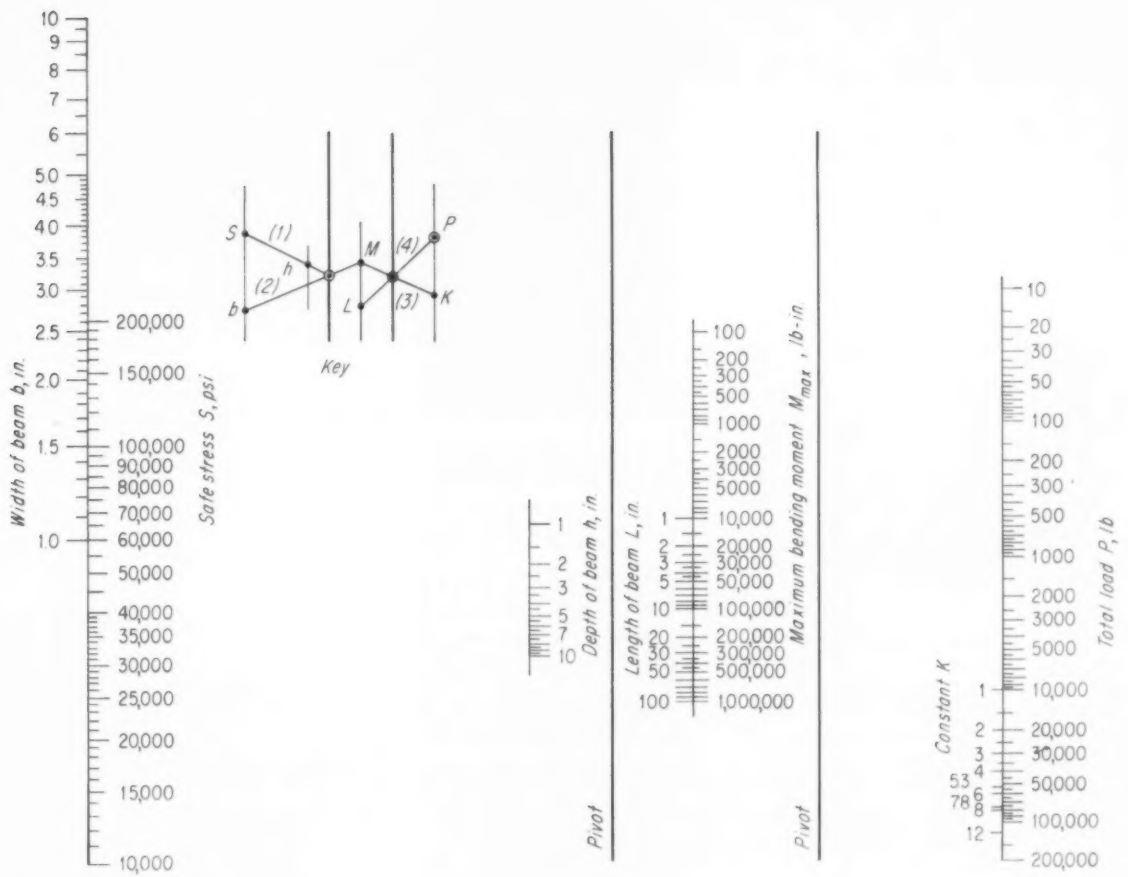
SYMBOLS

- b = Maximum width of beam, in.
- c = Distance from neutral plane to outer fiber, in.
- h = Maximum depth of beam, in.
- I = Rectangular moment of inertia about neutral axis, in.^{4}
- K = Constant whose value depends on loading and support
- L = Length of beam, in.
- M = Bending moment, lb-in.
- P = Total load on beam, lb
- S = Safe stress, psi

Type	K		Type	K	
13	8	Parabolas; P = total load	16	8	
14	8	P = total load; Half ellipse	17	12	P = total load
15	8	P = total load	18	12	P = total load



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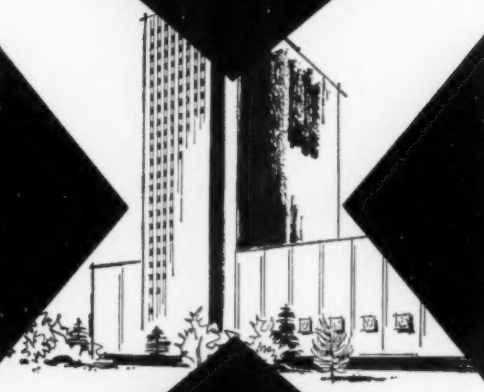

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SIGNIFICANT COMPONENTS MATERIALS, PROCESSES

Face-type shaft seals . . .

can be disassembled and reassembled by hand, cutting tooling costs for small-volume users. From stock in sizes up to 4 in., they conform to all standard face-type cartridge seal dimensions and can replace these in the field. Said to provide improved sealing by use of standard O-ring packings and Teflon-coated inner sealing surfaces. Aluminum in both adapters and outer shells minimize inertia losses. Prices reportedly run "substantially lower" than standard face-type cartridge seals. **Gits Bros Mfg Co, 1866 S Kilbourn Ave, Chicago 23.**

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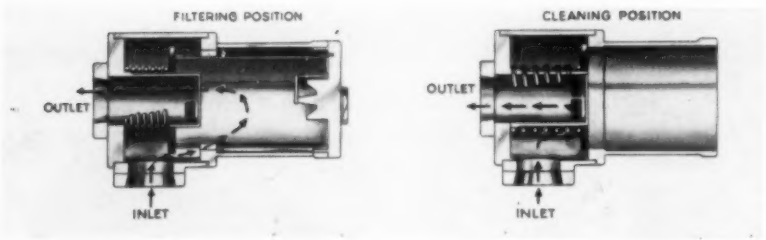

Submersible filter . . .

projects through hole in wall of tank when submerged. Need for cleaning is shown by dirt indicator on cover plate, and unit can be cleaned from outside the tank without draining tank or shutting off valves. Outlet pipe can project from top, bottom or from either end using a single elbow (can be placed straight across and out back without any elbow). Sizes include 30 and 60 gpm. **Rosaen Co, 1776 E Nine Mile Rd, Hazel Park, Mich.**

Circle 301 on Reader Service Card

Glass filament-wound epoxy tubing . . .

is said to top burst-strength properties of G-10 grades by about 3 to 1. Made by use of continuous strands of glass filaments that are bathed in epoxy resin, helically wound and then heat cured, the tubing reportedly makes it possible to achieve exact ratios between burst and tensile strengths. Available in variety of circular sizes and lengths or in such special cross-section shapes as rectangular. Also can be furnished in combination with vulcanized fibre tubes or metal inserts. **Spaulding Fibre Co Inc, 310 Wheeler St, Tonawanda, NY.**

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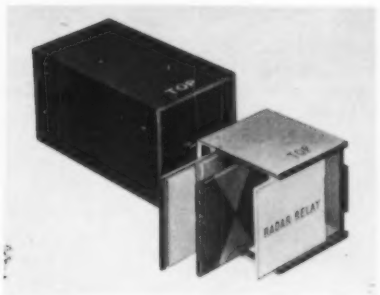
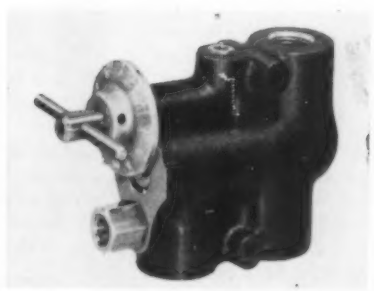


Indicator-light capsules . . .

use white lamps and a color filter to illuminate legend areas in three colors. Two MS-327 or MS-328 lamps are provided for each color in the filter. Comprising miniaturized circuitry and components, units can be mounted in compact modular arrangements flush with panel—stacked either side-by-side or vertically. For maintenance, single light assembly can be removed from a stack without disturbing others. Color filters, nomenclature strips and lamps are changed by pressing on lens to eject. Two models are available—one a pushbutton type incorporating from one to eight microswitches. Priced from $22.50 to $35. Delivery in 30 days. **Radar Relay Inc, 2322 Michigan Ave, Santa Monica, Calif.**

Circle 303 on Reader Service Card



Flow-divider valve . . .

is dial-operated, simplifying flow-rate selection for hydraulic systems. Systems incorporating this valve are operated by fully pressure-compensated controlled flow, rather than bleed-off type arrangement using a flow regulator. Dial is a manually operated, detent-positioned unit that permits selection of up to 10 different rates

continued on page 52

of flow from a constant delivery pump. It can be set to provide calibrated increments of controlled flow to meet specific capacity requirements of the motor—or, it can be adjusted to suit varied operating conditions. Flow rate is adjustable from zero to rated capacity. Once it is selected and set, motor speed is maintained regardless of load or pressure demands, with a built-in relief valve protecting the controlled flow circuit. Fluid in excess of amount delivered to valve's controlled flow port can be used to operate another completely independent system. Valve handles all standard hydraulic fluids at temperatures up to 250 F. Available in two sizes—one with controlled flow from 0 to 15 gpm and rated input of 15 gpm and another with controlled flow up to 60 gpm with 80-gpm rated input flow. **Hydraulic-Electronic Div, Fawick Corp, 9919 Clinton Rd, Cleveland 11.**

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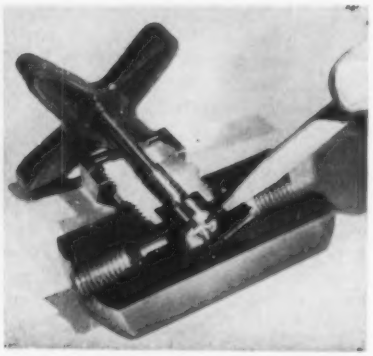

High-pressure shut-off valve

is equipped with Teflon seat which is compressed into a positive sealing O-ring. As free-turning Monel stem is screwed down to closed position, a portion of the seat is forced from its stainless steel swivel cage (attached to stem), forming a Teflon-to-metal seal. Cage's swivel design is said to eliminate galling as valve is closed. Rated 10,000 psi the 18-8 stainless steel valve is easily opened and closed under extreme pressure. When valve is closed, stem packing can be replaced without removing unit from line. Available in four sizes from ¼ to ¾ in. **Clayton Mark & Co, 1900 Dempster St, Evanston, Ill.**

Circle 305 on Reader Service Card

Vortex-velocity flowmeters . . .

in 6-, 8- and 16-in. sizes, measure gas or liquid flow at high pressure. In the vortex-velocity principle of flow measurement, the meter presents an offset chamber in side of pipe in which a natural vortex is allowed to develop. This vortex rides on pipe's main stream like a pulley on a belt. A linear relationship exists between vortex's number of revolutions and main flow's volume, and volume flowing though meter is read by counting revolutions of the rotor within the vortex. Rotation of rotor is transferred to outside of meter by magnetic couplings and can be presented as a flow rate and/or an integrated flow signal. Flow range and capacity of meter depend on fluid properties and degree of accuracy required without applying calibration factors. Each meter is fitted with an adjustable internal bypass which serves as both a range adjuster and calibrator. From stock. **Rotron Controls Corp, Woodstock, NY.**

Circle 306 on Reader Service Card

Nylon epoxy "prepregs" . . .

with satin or straight weaves, are available in 37-in. widths, off white in color. Weight of satin weave prepreg is 0.81 lb per sq yd with monofilament nylon of 840 denier, 5 harness weave containing 40% B-stage epoxy resin. Drape characteristics of the satin weave are said to be advantageous in molding shapes and contours. Typical tensile test results at 159.8 F show modulus of 25,000, ultimate strength of 12,600 psi, and yield of 3400 psi for a random lay-up. Resin has approx 20% flow at 289.4 F and volatile content of less than 1.5%. Tacky surfaces adhere in laminating. Straight weave prepreg has similar characteristics. **Westinghouse Electric Corp, Micarta Div, Trafford, Penna.**

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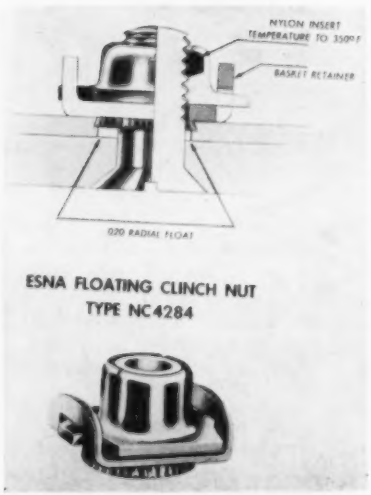

Floating clinch nut . . .

for blind fastening, has two small lugs in a window-type basket retainer, providing a 0.020-in. radial float. This float enables nut to automatically compensate for minor bolt hole misalignment of components being attached. Bracket has a short, knurled shank which is swaged flush into a punched or drilled hole in aluminum or soft steel sheets. Self-locking nut, made in carbon or stainless steel, is available in machine screw sizes #4, 6, 8 and 10. Series of three baskets with alternate shank lengths of 0.040, 0.060 or 0.090 in. is offered for each thread size. Locking device is nylon insert which withstands temperatures up to 350 F. **Sales Engineering Dept, Elastic Stop Nut Corp of America, 2330 Vauxhall Rd, Union, NJ.**

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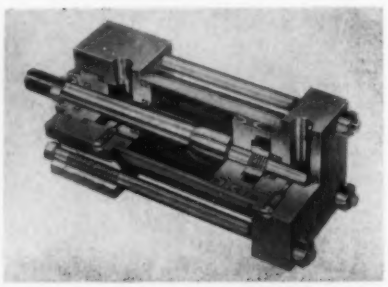


Cushion-type air cylinders . . .

in 1⅛ through 14-in. bore sizes, are suitable for working pressures to 250 psi and temperatures from —40 to 250 F. High tensile steel tie-rod construction is said to provide max strength, eliminate axial loading of tubes and increase shock loading capacity. Easily-serviced rod cartridge is removable with only a wrench and has dual-purpose O-rings to seal and maintain tension-preventing longitudinal motion. Dimensionally interchangeable units meet or exceed JIC standards. **Sheffer Corp, 326 W Wyoming Ave, Cincinnati 15.**

Circle 309 on Reader Service Card

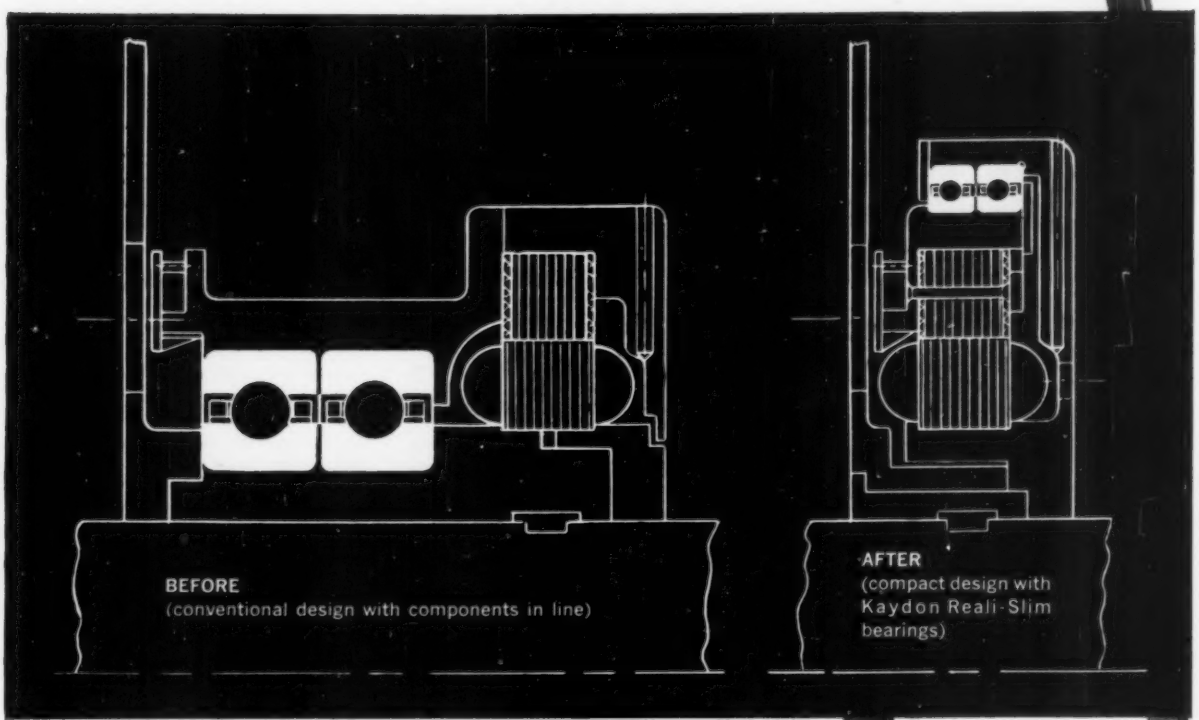
High-speed clutches . . .

available for variety of tractor drives, have counterbalanced release lever design, which permits high speed operation without increasing pressure required to release. Anti-friction roller action of the release levers is said to give instantaneous disengagement with min pedal pressure and longer lever life. The spring-loaded, dual-drive clutches contain built-in provision for live power takeoff. This auxiliary drive runs constantly

continued on page 54

Don't let in-line design get in the way of a compact product...

"NEST" COMPONENTS INSIDE THE BEARING BORE



Motor assembly redesign shown above is typical of the way Kaydon Reali-Slim bearings save space, reduce weight, cut costs!

Kaydon thin-section Reali-Slim bearings provide valuable component space inside the bearing bore. And use of a hollow shaft permits utilizing this space for control rods, linkages, collets, counter-rotating shafts, clutches and brakes, to name a few possibilities.

With Reali-Slim bearings, you save weight and space in both bearing and housing, reducing costs for materials, shipping, storage and handling.

And large-bore Reali-Slim bearings give closer support to the outer edge of rotating parts, instead of the center only, which gives more rigidity and accuracy for moment loads.

Stocked in 90 sizes! These Kaydon Reali-Slim Type CP bearings have Conrad deep-groove, ball-radial construction and new bronze, one-piece snap-over separator in 4" to 12" bore—¼" to 1" width and cross section. Kaydon's volume production cuts prices up to 76%, depending on size.

Contact Kaydon now. Have the Kaydon sales engineer or distributor salesman in your area discuss Reali-Slim bearing applications for *your* products. Or write for free, fact-full "CP" bearing bulletin—with prices.

Shown here is an actual size KA-90-CP bearing, with 9" bore, ¼" cross section and ¼" width

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K-609R

from flywheel through a splined hollow shaft. Wide range of torque capacities depend on choice of engagement springs and friction materials. **Rockford Clutch Div, Borg-Warner Corp, Rockford, Ill.**

Circle 310 on Reader Service Card

Miniature switchlight . . .

is a DPDT snap-acting unit that combines two switching functions with separate, but related, lamp indication. Simple screwdriver adjustment, before or after installation, zeros switch at both poles for simultaneous switching. All components are contained in one anodized aluminum case, with individual lamp and switch terminals located in rear turret arrangement. Color coding is provided by non-rotating pushbutton lenses in all standard clear or translucent colors. Both front and side illumination is available with the snap-on lenses. Unit is said to last for 25,000 operating cycles at 28 v dc with 7-amp resistive load. Lamps are standard two-pin, plug-in models with operating voltages from 5 to 28 v dc. **Eldema Corp, 1805 Belcroft, El Monte, Calif.**

Circle 311 on Reader Service Card

Five-digit impulse counter . . .

contains rectifier to provide dc operation directly from a 110-v ac source. Surface-mounted unit has a rated counting speed of 667 counts per min. and is said to last for at least 100 million counts. Can be used with any pulse generator capable of creating a pulse of the required specifications. Its coil can be continuously energized. Depressing a pushbutton on the counter surface instantaneously resets all counting drums to zero. Unit, measuring $1\frac{31}{32}$ x $2\frac{3}{4}$ x 3 in., can be remotely located from units or operations being counted. Figures are engraved while on black type. **Landis & Gyr Inc, 45 W 45th St, New York 36.**

Circle 312 on Reader Service Card

Synthetic-rubber adhesive . . .

allows parts assembly within 2 to 5 min. after application. Said to be highly effective in bonding porous materials such as urethane foam to metal. Recommended for adhering to steel, aluminum, brass, glass, neoprene, GR-S, Buna-N, phenolic, urea, polystyrene, fiberglass, felt, cork, masonite, leather, nylon, sponge urethane, sponge rubber and enameled surfaces. Can be applied in three ways: two-way dry stick; two-way wet stick; and two-way solvent activation. Pinkish tan in color, it has a solids content of 28 to 30% by weight and consistency of thin syrup. **Bostik Dept, B B Chemical Co, 784 Memorial Dr, Cambridge, Mass.**

Circle 313 on Reader Service Card

Circuit protector . . .

is a sealed, dc-operated, nonpolarized, electromagnetic fault or overload current limiting device that resets itself. Speed of operation depends upon overload magnitude, within 1 to 10 millisec of fault occurrence. Trips within 10% of specified current. Allows testing or sampling of various loads without shutdown in event of a fault condition at any point. If fault occurs, unit automatically resets when switched to next point. Auxiliary contacts provide control for alarm or recording of when and where fault occurs. Priced at $15.50 each in quantities of 1 to 9. Delivery from stock or in 5 wk. **North Electric Co, Electronetics Div, Galion, Ohio.**

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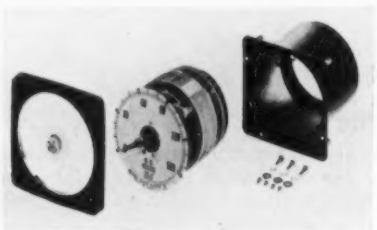

Long-scale instruments . . .

both ac and dc types, have pointers that move over a 250° arc scale more than 7 in. long. Suitable for control and distribution switchboards where readings need to be made at considerable distances, instruments accomplish long scale reading with accuracy of 1% of full scale value and in a panel size of only $4\frac{1}{2}$ in. Among ac devices available are ammeters, voltmeters, wattmeters and varmeters (single phase, polyphase, 3 phase 3 wire, 3 phase 4 wire), and frequency meters. Dc devices include ammeters and voltmeters. Ranges are: ammeter, 5-amp coil or self-contained to 20 amp; voltmeter, 150-v coil or self-contained to 800 v; and wattmeter, 5-amp, 150-v coils. All have magnetic shielding, one magnetic shunt calibration adjustment and front window zero adjuster that does not block scale and eliminates need for special tool to get zero indication. Ac ammeters and voltmeters operate on iron repulsion principle with air damping, while wattmeters and varmeters are of the dynanometer type with magnetic damping. Prices start at $93. **Federal Pacific Electric Co, 50 Ave L, Newark 1, NJ.**

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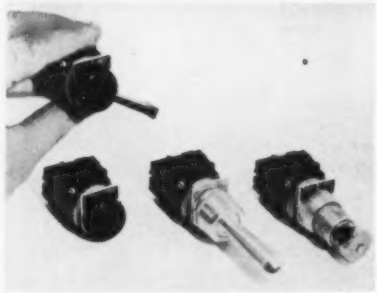


Miniature pushbuttons . . .

include four new forms: bat lever selection switch; coin-operated selector switch; wobble-stick operator and cylinder lock selector switch. Separable operators, contact blocks, rings, selector switch knobs, illuminated forms and color caps are available to provide "building block" construction and wide variety of combinations. Miniature forms now equivalent in price to similar units in heavy-duty pushbutton line. **General Electric Co, Schenectady 5, NY.**

Circle 316 on Reader Service Card

Cubicles and panels . . .

in stock sizes, are made of heavy-duty #10 gage steel. Cubicles, with 2 x 2 x $\frac{3}{16}$-in. angle iron frames, are prime coated or painted and include full rear doors—with or without gasketing, butt hinges and 3-point locks. Sizes available are 72 in. high x 24 in. deep and 24, 36 and 48 in. wide. Panels have 2 x 2 x $\frac{3}{16}$-in. reinforcing angles across top and bottom with 3-in. turnbacks on sides. Available with or without rear floor supports in 72-in.-high, 24-, 36- and 48-in. wide sizes. **Armesco Inc, Lansing & Bingham Sts, Philadelphia 11.**

Circle 317 on Reader Service Card

Slow-speed tape reader . . .

is a photoelectric unit that reads any kind of 5-, 7- or 8-hole perforated paper tape at rates up to 20 characters per sec. Measures 6 x $4\frac{3}{8}$ x 4 in. and has no contacts, brushes, motors, clutches and switches normally used in slow-speed tape readers. Includes all-solid state-circuitry, positive tape indexing, up to 60% light transmissivity and low-temp light source

that does not affect photocells. Available with a case for bench use, without case for OEM mounting or with 19-in. front panel for mounting in standard relay racks. Priced at $395 with optional amplifiers and drive circuitry. **Invac Corp, 14 Huron Dr, Natick, Mass.**

Circle 318 on Reader Service Card

Size-11 magnetic clutches and brakes . . .

have output torques of 80 oz-in. with low power consumption of 3 w at 24 v dc. Contain no slip rings and have zero backlash and endplay. Clutching and braking action is accomplished without angular displacement or axial motion. Input and output shafts are concentric with servo mounting pilot within 0.0015 TIR and precision ball bearings are shielded where required. Average characteristics at 24 to 28 v dc include: breakaway torques of 0.15 oz-in.; max engagement times of 15 millisec; output inertia of 0.026 oz-in.^{2} for both clutch and brake; and input inertia of 0.097 oz-in.^{2} for clutch. Standard temperature range is —67 to 248 F. Max recommended speed is 5000 rpm. **Guidance Controls Corp, 110 Duffy Ave, Hicksville, LI, NY.**

Circle 319 on Reader Service Card

Hi-temp valve . . .

is for either gas or liquid service at temperatures up to 1000 F and pressures to 30,000 psi. Even higher fluid temperatures can be used if valve body is well insulated and packing area well ventilated. An elongated stuffing box removes packing from "hot zone" in valve body itself. Two-piece stem which does not rotate against seat, is included, eliminating possibility of seat or stem being galled or scored. **Autoclave Engineers Inc, 2947 W 22nd St, Erie, Penna.**

Circle 320 on Reader Service Card

Radius-cornered hexagon rods

are available in all standard sizes. Rounded corner design, formerly a special radius service, is said to provide rod weight saving (averaging ½%), longer screw machine life, increased rod size capacity and less rod damage. Primarily made in free-cutting brass, rods also can be furnished in naval and leaded naval brasses, manganese bronze, nickel-silver and other alloys. Used for making bolts, nuts, hydraulic and automative fittings and other parts where the hex serves as a wrenching shape and priced at no increase over cost of regular sharp-cornered hex rods. **Titan Metal Mfg Co, Div. of Cerro Corp, Bellefonte, Penna.**

Circle 321 on Reader Service Card

DESIGN LITERATURE

Handbook of Consulting Practice for Mechanical Engineers

American Society of Mechanical Engineers, 29 W 39th St, NY 18. 6 x 9, 32 pp. $2.

This handbook sets forth the proper approach in obtaining professional engineering services, in establishing the fundamental structure for engineering agreements, and in determining the general conditions that should apply to the conduct of engineering assignments under various types of agreements.

Although this publication has been copyrighted, the Engineers Joint Council gives permission for it to be adopted and reprinted as a whole by any professional engineering society of this country on application in writing—so that records may be kept. Such societies may issue their own copies and include in an appendix those practices which are important to them but are not discussed in this publication.

Linear System Analysis

PAUL E PFEIFFER. McGraw-Hill Publishing Co Inc, 330 W 42nd St, NY 36. 6¼ x 9¼, 538 pp. $12.50.

Because it is intended chiefly as an undergraduate text, this book can serve as an introduction to the theory and methods of linear-system analysis for engineers whose advanced math has gotten a little rusty. The author has thoughtfully provided refresher courses in all those phases of mathematics, beyond calculus, needed to understand the theory of linear systems. In a space of some 30 pages, Chapter 2 reviews such mathematical topics as complex variables, polynomials, rational functions and determinants. And later chapters take up linearized dynamic equations, Laplace transforms, transfer functions and matrices. For the practicing engineer, the author, professor of electrical engineering at Rice University, offers this advice: The first several chapters will "put you in touch with the essential theory needed for application without requiring too much theoretical background." The person who is prepared to work at a more advanced level may find Chapter 8 ("Some Mathematical Properties of the LaPlace Transformation") and Chapter 9 ("The Transfer Function") of interest. In particular, Chapter 9 wraps up a great deal of the important theoretical development of discrete-parameter time-invariant linear systems.

Other Books of Interest

The Dynamical Theory of Sound

Horace Lamb. Dover Publications Inc, 180 Varick St, NY 14. 5¼ x 8, 304 pp. $1.50.

Unaltered paperback edition of second edition originally published in 1925.

ASTM Standards on Petroleum Products and Lubricants

American Society for Testing Materials, 1916 Race St, Philadelphia 3, Penna. 6 x 9¼, 1125 pp. Members $7.60; others $9.50.

ASTM Specifications for Steel Piping Materials

American Society for Testing Materials, 1916 Race St, Philadelphia 3. 6 x 9¼, 521 pp. Members $5.60; others $7.

Management Guide to Applied Industrial Psychology

B T Lewis, W W Pearson. John F Rider Publisher Inc, 116 W 14th St, NY. 5½ x 8½, 80 pp. $1.50.

High-frequency Magnetic Materials

W J Polydoroff. John Wiley & Sons Inc, 440 Park Ave South, NY 16. 6 x 9¼, 220 pp. $9.

ABSTRACTS FROM THE LITERATURE

Electrical Contacts

Tables and charts give the most suitable materials for contact points together with contact diameters. Manufacturers' code numbers for all alloys are also given in a cross-reference table.

"Let's Take Some of the Mystery Elements Out of Electrical Contacts," by Childress B. Gwyn Jr, Gibson Electric Co. Published in NARM Relay Symposium Papers at 8th Annual Relay Symposium at Stillwater, Okla.

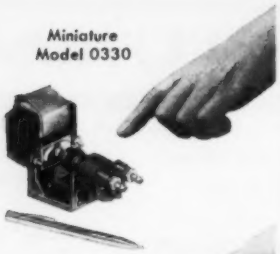
Reliability of Pilot Lights

The principal ways in which malfunction can occur in pilot lights are described and some of the ways in which these problems can be minimized or eliminated are discussed.

"Reliability of Industrial Pilot Lights As Indicating Devices," D. L. Pettit, Square D Co. AIEE paper CP 61-106. American Institute of Electrical Engineers, 33 W 39th St, New York 18.

continued on page 57

Miniature
Model 0330



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Model
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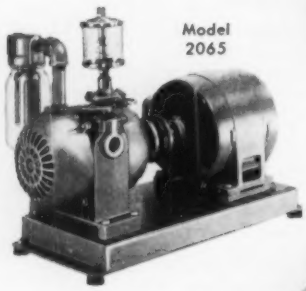

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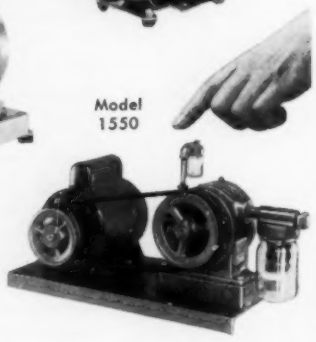

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VACUUM.....To 28" Hg.	VACUUM.....To 25" Hg.
PRESSURE.....To 30 p.s.i.g.	PRESSURE.....To 15 p.s.i.g.
MOTORS.....1/12 to 5 h.p.	MOTORS....1/40 to 1½ h.p.
DRIVES.....Integral-motor, Direct coupled, V-belt	DRIVES.....Integral-motor, Direct coupled, V-belt

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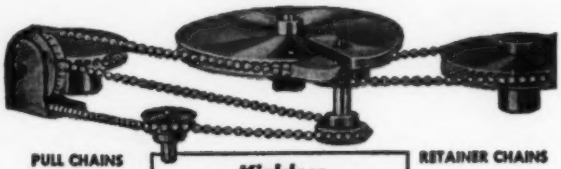

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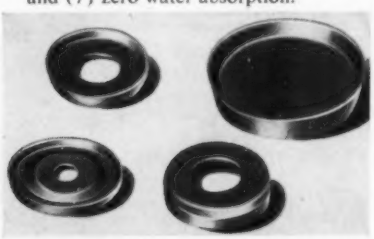

RULON now serves in pumps, valves, motors, compressors and scores of other products manufactured by leading companies across the nation. Dixon offers the widest variety of basic shapes, both in RULON and Teflon . . . plus engineering capability to formulate special reinforced fluorocarbons for special needs. Also, Dixon can supply molded, machined, stamped, cut or extruded parts to meet your print.

See our guide-book on RULON, Bulletin #9572, in Sweet's Product Design File or send details for recommendations. DIXON CORPORATION, 103 BURNSIDE ST., BRISTOL, R. I.

* DuPont T.M.

DIXON

Metric Conversion—Con

This paper summarizes a number of the technological and other arguments against conversion of the present US system of measurement to the metric.

"Physical Standards and Units of Measurement," R. P. Trowbridge, General Motors Corp. SAE paper 287B. SAE, 485 Lexington Ave, New York 17.

Viscosity

Two-part article discusses basic concepts; equipment for measuring viscosity; viscosity-temperature relationships; effects of shear, pressure, nuclear radiation; film lubrication; flow in pipes.

"Viscosity," Lubrication, Jan-Feb, '61. Texaco Inc, 135 E 42nd St, New York 17.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

FASTENERS—Catalog 161, 20 pp. Contains size ranges, materials available, physical and mechanical requirements, lockingability data and welding information for production runs on lock, clinch, weld, special and semifinished nuts. Grip Nut Co, Sub of Heli-Coil Corp, South Whitley, Ind.

Circle 350 on Reader Service Card

PHOTOELECTRIC CONTROLS—Bulletin 611, 22 pp. Mechanical and electrical characteristics are given for miniaturized "electric eyes," ranging from light sources and photo units to time delays. Includes photographs and schematics of diversified photoelectric systems and discussion of photoelectric control advantages. Photomation Inc, 96 S Washington Ave, Bergenfield, NJ.

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ELECTRONIC CONTROL METERS—Data file, approx 12 pp. Carries exploded views of two continuous-output models and schematics showing their output vs scale length, input voltage and temperature. Standard ranges and specifications are outlined and dimensions are illustrated. International Instruments Inc, 88 Marsh Hill Rd, Orange, Conn.

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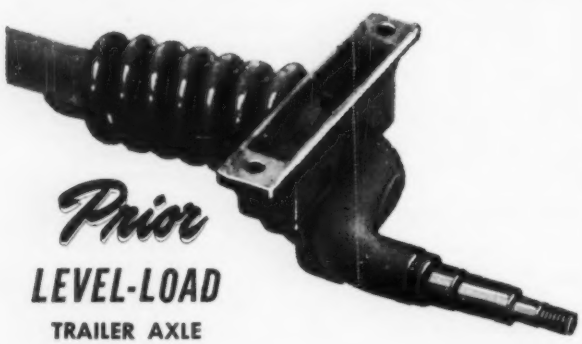

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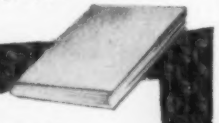

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A

Aeroquip Corp. 13
American Viscose Corp. 11
Anchor Coupling Co., Inc. 23

B

Barksdale Valves 14
Bead Chain Mfg. Co., Inc. 56

C

Chiksan Co. 19

D

Dietzgen Co., Eugene 12
Dixon Corp. 57

G

Gast Mfg. Corp. 56
General Aniline & Film Corp., Ozalid Div. 7

H

Hitchiner Mfg. Co. 57
Houdaille Industries, Inc., Buffalo Hydraulics Div. 22

I

International Nickel Co., Inc. 9

K

Kaydon Engineering Corp. 53

L

Lepel High Frequency Laboratories, Inc. 56

M

McGraw-Hill Book Co., Inc. 60

N

Norgren Co., C. A. .....3rd Cover

P

Prior Products, Inc. 58

R

Reuland Electric Co. 48

S

Society of the Plastics Industry 50
Speco, Inc. 59
Spray Engineering Co. 59
Stevens Mfg. Co., Inc. 2

T

Timken Roller Bearing Co., Steel & Tube Div. 5

V

Vickers, Inc., Div., Sperry Rand Corp. .....2nd Cover
Vulcan Electric Co. 24

W

Wagner Electric Corp. .....4th Cover

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Employment Opportunities 58

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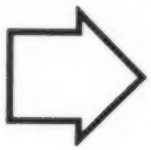

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2	22	42	62	82	102	122	142	162	182	202	222	242	262	282	302	317	332	347	362	377
3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	318	333	348	363	378
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	319	334	349	364	379
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	320	335	350	365	380
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	321	336	351	366	381
7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	322	337	352	367	382
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	323	338	353	368	383
9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	324	339	354	369	384
10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	325	340	355	370	385
11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	326	341	356	371	386
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	327	342	357	372	387
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	328	343	358	373	388
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	329	344	359	374	389
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	330	345	360	375	390
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296						
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297						
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298						
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299						
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592 593 594 595 596 597 598 599 600 601 602 603

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313—Synthetic Rubber Adhesive

POWER TRANSMISSION

310—High-speed Clutches

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FABRICATION PROCESSES AND PRODUCTION

354—Blow Molding, 18 pp, Hercules Powder Co.

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350—Fasteners, 20 pp, Grip Nut Co, Sub of Heli-Coil Corp.

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351—Photoelectric Controls, 22 pp, Photomation, Inc.

362—Synchronous Ac Generators, 2 pp, Electric Machinery Mfg Co.

ELECTRICAL, ELECTRONIC COMPONENTS

351—Photoelectric Controls, 22 pp, Photomation Inc.

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361—Dc Power Supplies, 16 pp, Valor Instruments Inc.

362—Synchronous Ac Generators, 2 pp, Electric Machinery Mfg Co.

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MECHANICAL PARTS

300—Face-type Shaft Seals

317—Cubicles and Panels

321—Radius-cornered Hexagon Rods

FASTENING AND JOINING

308—Floating Clinch Nut

313—Synthetic Rubber Adhesive

ELECTRICAL, ELECTRONIC COMPONENTS

303—Indicator Light Capsules

311—Miniature Switchlight

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315—Long Scale Instruments

316—Miniature Pushbuttons

318—Slow-speed Paper Tape Reader

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3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	318	333	348	363	378
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	319	334	349	364	379
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	320	335	350	365	380
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	321	336	351	366	381
7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	322	337	352	367	382
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	323	338	353	368	383
9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	324	339	354	369	384
10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	325	340	355	370	385
11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	326	341	356	371	386
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	327	342	357	372	387
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	328	343	358	373	388
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	329	344	359	374	389
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	330	345	360	375	390
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296						
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297						
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298						
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299						
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300						

REPRINTS

580	581	582	583	584	585	586	587	588	589	590	591	
592	593	594	595	596	597	598	599	600	601	602	603	

*MULTIPLE PRODUCT ADS	
Key No.	Specific Product

(please print or type) *If this is change of address, check box* ☐

Name.....Title.....

Street.....

City.....Zone.....State.....

Company.....Major Product Manufactured.....

1	21	41	61	81	101	121	141	161	181	201	221	241	261	281	301	316	331	346	361	376
2	22	42	62	82	102	122	142	162	182	202	222	242	262	282	302	317	332	347	362	377
3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	318	333	348	363	378
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	319	334	349	364	379
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	320	335	350	365	380
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	321	336	351	366	381
7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	322	337	352	367	382
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	323	338	353	368	383
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16	36	56	76	96	116	136	156	176	196	216	236	256	276	296						
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580	581	582	583	584	585	586	587	588	589	590	591	
592	593	594	595	596	597	598	599	600	601	602	603	

*MULTIPLE PRODUCT ADS	
Key No.	Specific Product

INDEX OF PRODUCTS ADVERTISED IN THIS ISSUE

After reading the advertisements classified below . . . MORE DETAILED INFORMATION about these products can be obtained by using the attached READER SERVICE CARD.

A

Actuators
- Mechanical 22

Axles 58

Air Motors (see Motors, Air)

B

Bearings
- Ball 53
- Needle 53
- Roller 53

Books 60

C

Castings, Precision Investment 57

Chains
- Bead 56

Chromium Alloys 9

Coatings 59

Compressors 56

Connectors
- Hose 23
- Tube 23

D

Drafting
- Instruments 12
- Machines 12
- Supplies 12

F

Fibre 11

Fittings, Hose, Pipe & Tube 13, 23, 59

Furniture, Engrg. Dept. 12

G

Gear Motors (see also Motor Reducers) 48

H

Heating Units 24, 56

Hose & Tubing 13

J

Joints
- Swing & Swivel 19

M

Motor Reducers (see also Gear Motors) 48

Motors, A-C
- Fractional ..... 4th Cover
- Integral ..... 4th Cover

Motors, Air 56

Motors, D-C
- Fractional ..... 4th Cover
- Integral ..... 4th Cover

Motors, Hydraulic ..... 2nd Cover

N

Nickel Alloys 9

Nozzles 59

P

Plastics 50, 57

Plastics Fabricated 57

Power Packs
- Hydraulic ..... 2nd Cover

Pressure Switches 14

Pumps
- Air 56
- Vacuum 56

R

Regulators
- Pneumatic ..... 3rd Cover

Reproduction Equipment 7, 12

Reproduction Supplies 7, 12

Revolving Joints (see Joints, Swing & Swivel)

T

Thermostats 2

Tubing
- Seamless 5

W

Whiteprinting Equipment 7

Issue of May 8, 1961
PRODUCT ENGINEERING
Card expires July 7, 1961

FIRST CLASS
PERMIT No. 64
NEW YORK, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed in the United States

Postage Will Be Paid By Reader Service Department

Inquiries Services Department
PRODUCT ENGINEERING
P.O. Box 601
Ridgefield, Connecticut

Issue of May 8, 1961
PRODUCT ENGINEERING
Card expires July 7, 1961

FIRST CLASS
PERMIT No. 64
NEW YORK, N. Y.

BUSINESS REPLY MAIL
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Postage Will Be Paid By Reader Service Department

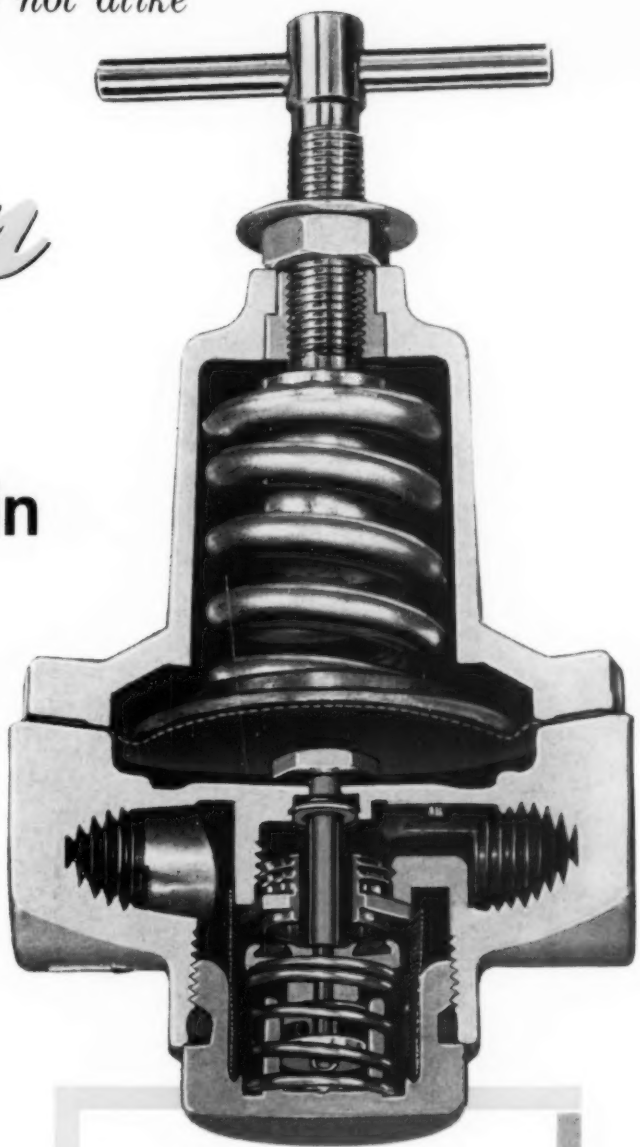
Inquiries Services Department
PRODUCT ENGINEERING
P.O. Box 601
Ridgefield, Connecticut

All Pressure Regulators are not alike

Norgren

Floating Valve-Pin

A Norgren extra that assures leak-proof seating of the regulator valve



A tight, leak-proof seating of the valve is essential to the proper performance of a pressure regulator. Leakage and creep can be caused by improper alignment of the valve-pin, resulting in gouges and excessive wear on the valve seats.

To prevent this, Norgren Regulators are made with a floating valve-pin, eliminating critical alignment problems. The Norgren floating valve-pin is self-aligning, assuring positive seating of the valve. As a result, there is minimum wear on the valve seat, with increased service life and more dependable regulator performance.

Whatever your pressure regulation need, there is a Norgren Pressure Regulator designed for the job. Call your nearby Norgren Representative listed in your telephone directory—or write factory for literature showing complete Norgren Regulator line.

Norgren Pressure Regulators give you these important features:

Balanced Valve Construction—
improved regulator performance

Large Nylon-reinforced Synthetic
Rubber Diaphragm—long service life

Baffle and Siphon Tube—
increased accuracy

Large Passages and Valve Openings—
large flow capacity

Easy servicing while still on fluid-line

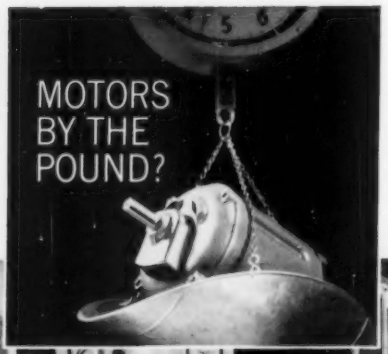
Floating Valve-Pin—
assures better seating

FOUNDED IN 1926

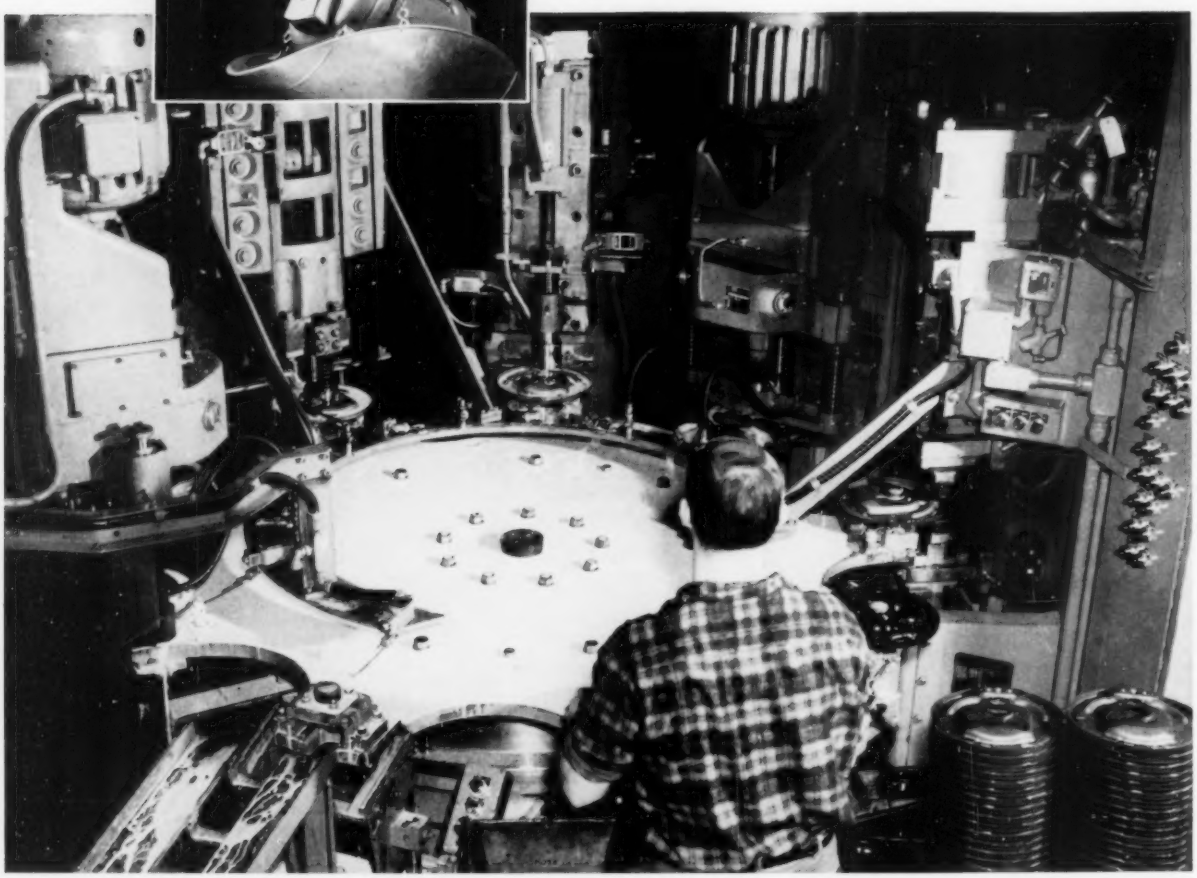
C. A. NORGREN CO.

3428 SOUTH ELATI STREET • ENGLEWOOD, COLORADO

CIRCLE 202 ON READER SERVICE CARD



You're buying motors by the pound when price is the only consideration



Today's machine tools can't afford motors selected on the basis of price alone

Modern machine tools are designed to manufacture products of great precision at the lowest possible cost. But a machine tool is only as productive as the electric motors that drive it. Motors purchased on the basis of price alone often fail to give their users the greatest value in terms of useful service life.

The selection of the right motor to power your products requires not only specification of type, rating and operating characteristics, but consideration of such factors as uniform, troublefree performance, dependable long-life operation, the reputation of the manufacturer, and his ability to provide immediate repair parts and service —when and where they're needed. Wagner® motors have earned their reputation for proven dependability in their specific applications.

Next time you buy motors, check beyond the purchase price. Make sure that you get all the performance you need—with motors that will do the job.

Wagner motors have been getting the job done for more than 65 years. Your Wagner Sales Engineer will be glad to show you why. Call him for an analysis of your next motor application, be it for plant or product.

Branches and Distributors in all Principal Cities

Wagner Electric Corporation

6406 PLYMOUTH AVENUE, ST. LOUIS 33, MISSOURI

WM61-4

CIRCLE 203 ON READER SERVICE CARD